
SRF2025
TOKYO
22ND INTERNATIONAL CONFERENCE
ON RF SUPERCONDUCTIVITY
SEPTEMBER 21-26
CONFERENCE BOOK
RIKEN NISHINA CENTER
RIKEN

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22nd International Conference on RF Superconductivity
September 21-26, 2025

Ito International Research Center

Logo

The conference logo, created by Mr. Narumasa Miyauchi from RNC, is designed with the theme 'Particle Accelerators as the Foundation of Society.' The tall buildings are based on the RIKEN Linear Accelerator (RILAC). The word 'Tokyo' is creatively transformed, with the letter 'o' resembling the head of screw bolts and the letter 'y' forming a torque wrench—both essential tools for reliable engineering.

SRF2025 Chair welcome

It is my pleasure, on behalf of RIKEN Nishina Center and the SRF2025 organizing committees, to welcome you to the 22nd International Conference on RF Superconductivity (SRF2025) from September 21st to 26th in Tokyo. The conference series has a history of providing a vivid forum for SRF scientists, engineers, students and industrial partners to present and discuss the latest developments in the science and technology of superconducting RF for particle accelerators. For 2025 we move the conference series to Tokyo, Japan, one of the most exciting cities in the world.

The SRF Conference since its inaugural event in 1980, has been held every other year for over 40 years, rotating its location between Europe, North America, and Asia. Initially, discussions primarily focused on the development of high-performance cavities for the International Linear Collider, a high-gradient electron accelerator, leveraging the technology of superconducting RF. Recent progress of the cavity performance is outstanding introducing new materials and new surface processing recipe. Furthermore, in recent years, with the establishment of the basic technology of superconducting cavities, their introduction or consideration for large-scale user facilities for not only electron but also proton and heavy ions has been actively discussed. This has transformed the conference into a platform not only for the development of high-performance superconducting cavities but also for discussing technologies for a long-term operation in user facilities. Moreover, its application scope has rapidly expanded to detectors for dark matter, axions, gravitational waves, and quantum computers.

In 2020, SRILAC (Superconducting RIken Linear ACcelerator) achieved beam acceleration for the first time and has since entered the stage of long-term operation, resolving various issues of different sizes. In 2025, marking the fifth year of operation, RIKEN will host the conference. Over six days, researchers, and technicians from both domestic and international arenas in the field of superconducting RF will gather, engaging in a wide range of discussions from fundamentals to applications through oral and poster presentation sessions.

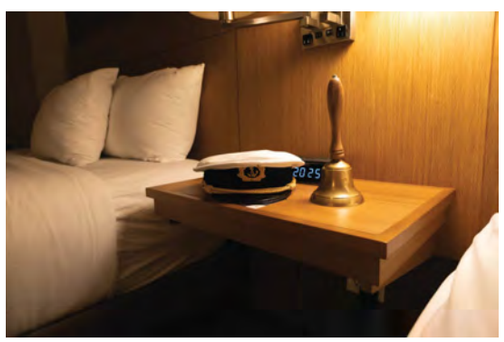
Tutorial sessions will be held before the conference from September 18th to 20th on the RIKEN Wako campus. A tour of the RIBF for nuclear physics research will be conducted on the last day of the conference.

Following the long and successful tradition, SRF2025 will feature invited and contributed talks, as well as poster sessions and an industry exhibition. A stimulating scientific program will be complemented by social events that promote informal knowledge exchange. There are several sponsorship opportunities for all those who would like to support the event and gain visibility.

The conference will provide opportunities for students to present their work. We anticipate being able to provide some financial support for a significant number of students from all regions to attend the conference. A student poster session will be held on Sunday in conjunction with the welcome reception. We look forward to welcoming you at Tokyo.

Sincerely,

Naruhiko Sakamoto
Conference Chair, SRF2025



Time Table

SRF'25@Ito hall						Time
21-Sep	22-Sep	23-Sep	24-Sep	25-Sep	26-Sep	
Sun	Mon	Tue	Wed	Thu	Fri	
	Registration 30	Venue opens at 8:00 AM				8:00-8:30
	Opening 20					8:30-9:00
	Oral session (8:50-10:30) 100	Oral session (8:30-10:30) 120	Oral session (8:30-10:30) 120	Oral session (8:30-10:30) 120	Oral session (8:30-10:30) 120	9:00-10:00
Venue setup (9-12)	Coffee(10:30-11) 30	Coffee(10:30-11) 30	Coffee(10:30-11) 30	Coffee(10:30-11) 30	Coffee(10:30-11) 30	10:00-11:00
	Oral session (11-13) 120	Oral session (11-13:10) 130	Oral session (11-13:10) 130	Oral session (11-13:10) 130	Oral session (11-12:40) 100	11:00-12:00
						12:00-13:00
Student Poster(13-15)	Lunch (13-14:30) 90	Lunch (13:10-14:30) 80	Lunch & Free Time (13:10-15:00) 110	Lunch (13:10-14:30) 80	Poster award presentations and closing 60	13:00-14:00
Registration (12-18)	Poster session (14:30-17:30) 60	Poster session (14:30-17:30) 60	Photo Session (15-15:30) 30	Poster session (14:30-17:30) 60		14:00-15:00
Reception (15-18)	Coffee 30	Coffee 30	Tokyo Bay Cruise Banquet (15:30-18) 150	Coffee 30	RIBF Tour	15:00-16:00
	Poster session 90	Poster session 90		Poster session 90		16:00-17:00
	Hot topic 1 (17:30-18:30) 60	Hot topic 2 (17:30-18:30) 60		Keynote 60	Return to Tokyo	17:00-18:00
						18:00-18:30

Sunday, September 21

Session SUP: Student Poster

Start	End				
13:00	15:00	SUP	Student Poster Session		

Monday, September 22

Session MOA Chair : Detlef Reschke (DESY) : Opening

Start	End	MOA	Category	Name (Affiliation)	Title
8:30	8:50	Opening			
8:50	9:10	MOA01	SRF Facilities	Naruhiko Sakamoto (RIKEN)	5 year operation of RIKEN SC-LINAC
9:10	9:30	MOA02	Fundamental SRF R&D	Thomas Proslier (CEA)	Crystallinity in Niobium oxides: A pathway for mitigation of Two-Level System Defects in Niobium 3D Resonator for quantum applications
9:30	9:50	MOA03	Cavities	Subashini De Silva (ODU)	EIC Crabbing Cavity RF Systems
9:50	10:10	MOA04	SRF Technologies	Yasuchika Yamamoto (KEK)	Specification, Design, Production and Test Schedule of Cryomodule for SRF 5-year Plan (MEXT-ATD) at KEK by Global Collaboration for ILC Technology Network
10:10	10:30	MOA05	SRF Applications	Alexander Romanenko (FNAL)	Recent advances in 3D SRF cavity based quantum computing facility at the Fermilab SQMS Center
10:30	11:00	Coffee			

Session MOB Chair : Kexin Liu (PKU) : SRF Facilities

Start	End	MOB	Category	Name (Affiliation)	Title
11:00	11:20	MOB01	SRF Facilities	Cecilia Maiano (ESS)	Commissioning of ESS superconducting linac
11:20	11:40	MOB02	SRF Facilities	Lauren Alsberg (SLAC)	LCLS-II Operation status and the LCLSII_HE upgrade
11:40	12:00	MOB03	SRF Facilities	Ting Xu (FRIB/MSU)	FRIB operation, status of power upgrade, and R&D for FRIB400
12:00	12:20	MOB04	SRF Facilities	Jinfang Chen (SARI-CAS)	Status of the SRF activities for the SHINE project
12:20	12:40	MOB05	SRF Facilities	Maksym Miski-Oglu (GSI)	Commissioning of the first HElmholtz LInear ACcelerators (HELIAC) cryomodule with heavy ion beam
12:40	13:00	MOB06	SRF Facilities	Muhammad Aburas (GANIL)	5 years of SPIRAL2 LINAC operation : Cryogenic and Superconducting RF Aspects
13:00	14:30	Lunch			

Session MOP : Poster

Start	End				
14:30	17:30	MOP			

Session Hot Topic 1 Chair : Robert Laxdal (TRIUMF)

Start	End				
17:30	18:30	HT1	Hot Topic	Arnaud Madur (CEA-Saclay), Jie Gao (IHEP), Robert Laxdal (TRIUMF), Sergey Belomestnykh (FNAL)	Sustainability of Accelerator Facilities

Tuesday, September 23

Session TUA Chair : Walter Venturini Delsolaro (CERN) : SRF Facilities/ Fundamental SRF research and development

Start	End	TUA	Category	Name (Affiliation)	Title
8:30	8:50	TUA01	SRF Facilities	Yuan He (IMP-CAS)	Recent Progress of SRF Linac Projects, HIAF and CiADS, at IMP
8:50	9:10	TUA02	SRF Facilities	Serena Barbanotti (DESY)	The path to High Duty Cycle (HDC) at EUXFEL: cryomodule development for a HDC upgrade of the European XFEL
9:10	9:30	TUA03	SRF Facilities	Rui Ge (IHEP)	Progress of CSNS-II SRF system
9:30	9:50	TUA04	Fundamental SRF R&D	Alena Prudnikava (HZB)	Studies of in-situ baking of SRF niobium cavities without a furnace at HZB
9:50	10:10	TUA05	Fundamental SRF R&D	Julia Goedecke (DESY)	Enhancement of medium-temperature heat-treated SRF cavities for high quality and high gradient with supporting sample investigations
10:10	10:30	TUA06	Fundamental SRF R&D	Lea Preece (U. Hambur)	SIS Multilayer Studies and Status of the new Cavity-Coating System at University of Hamburg
10:30	11:00	Coffee			

Session TUB Chair : Cristian Pira (INFN-LNL) : Fundamental SRF research and development/ Cavities/ SRF Technologies

Start	End	TUB	Category	Name (Affiliation)	Title
11:00	11:20	TUB01	Fundamental SRF R&D	Bektur Abdisatarov (FNAL)	Systematic study of annealing effects on RF properties of HiPIMS Nb film
11:20	11:40	TUB02	Cavities	Tomohiro Yamada (KEK)	Nb3Sn coating and conduction cooling R&D at KEK
11:40	12:00	TUB03	Cavities	Hui Tian (JLAB)/Rong-Li Geng (JLAB)	Advancements in HF-Free Bipolar Pulsed Electropolishing for Next-Generation Superconducting Cavities
12:00	12:20	TUB04	Cavities	Eduard Chyhyrynets (INFN-LNL)	Plasma Electrolytic Polishing of 1.3 GHz cavities
12:20	12:40	TUB05	Cavities	Patrick Tutt (FRIB/MSU)	Plasma processing of FRIB Low-Beta Cryomodules using Higher-Order Modes
12:40	12:55	TUB06C	SRF Technologies	Camille Cheney (IJCLab)	Plasma Processing Under the Microscope: A Multi-Diagnostic Investigation from Langmuir Probes to Cryogenic RF Tests in Low-Beta SRF Cavities
12:55	13:10	TUB07C	Cavities	Chahinez Boutelaa (IJCLab)	Impact of niobium carbide formation in superconducting RF cavities for particle accelerators
13:10	14:30	Lunch			

Session TUP : Poster

14:30	17:30	TUP			

Session Hot Topic 2 Chair : Akira Miyazaki (U. Paris-Saclay, CNRS/IN2P3, IJCLab)

17:30	18:30	HT2	Hot Topic	Claire Antoine (CEA-Saclay), Takayuki Kubo (KEK), Jinfang Chen(SARI-CAS), Sam Posen (FNAL), Genfa Wu	Development Toward Extremely High Performance Superconducting Cavities

Wednesday, September 24

Session WEA Chair : Tsuyoshi Tajima (LANL) : Cavities/ SRF Technologies

Start	End	WEA	Category	Name (Affiliation)	Title
8:30	8:50	WEA01	Cavities	Hayato Araki (KEK)	RF characterization of 1.3 GHz single-cell Nb/Cu full-seamless cavity manufactured by hydroforming
8:50	9:10	WEA02	Cavities	Troy Petersen (ANL)	Nb3Sn Superconducting Cavity Developments for Heavy-ion Beams
9:10	9:30	WEA03	SRF Technologies	Samuel Smith (CERN)	Towards high power tests of an FE-FRT for transient detuning
9:30	9:50	WEA04	SRF Technologies	Ziqin Yang (IMP-CAS)	First beam acceleration using cryo-cooled Nb3Sn coated cavity at IMP
9:50	10:10	WEA05	SRF Technologies	Rong-Li Geng (JLAB)	Beam acceleration with a Nb3Sn cryomodule at JLAB
10:10	10:30	WEA06	SRF Technologies	Jake Parsons (Cornell U.)	Performance of the Cornell Conduction-Cooled Nb3Sn Cavity Cryomodule
10:30	11:00	Coffee			

Session WEB Chair : Anna Grassellino (FNAL) : Fundamental SRF research and development

Start	End	WEB	Category	Name (Affiliation)	Title
11:00	11:20	WEB01	Fundamental SRF R&D	Hannah Hu (FNAL)	Insights on the Effect of N and O Impurities Towards Optimizing SRF Cavity Performance
11:20	11:40	WEB02	Fundamental SRF R&D	Daniel Turner (CERN)	Flux Ratcheting: Enhanced magnetic flux expulsion in SIS multilayer structures
11:40	12:00	WEB03	Fundamental SRF R&D	Daniel Bafia (FNAL)	Oxygen vacancies in niobium pentoxide as a source of two-level system losses in superconducting niobium
12:00	12:20	WEB04	Fundamental SRF R&D	Felix Kramer (HZB)	Direct measurement of magnetic fields generated in Nb3Sn samples during cooldown
12:20	12:40	WEB05	Fundamental SRF R&D	Nicole Verboncoeur (Cornell U.)	Measurements of RF Magnetic Field Limits of Nb and Nb3Sn
12:40	12:55	WEB06C	Fundamental SRF R&D	Steven Anlage (U. of Maryland)	Dynamics of Few-Trapped Vortices in Niobium at Microwave Frequencies
12:55	13:10	WEB07C	Fundamental SRF R&D	Sadie Seddon-Stettler (Cornell U.)	Effects of Thin Gold Layers on Performance of 2.6 GHz SRF Cavity

Thursday, September 25

Session THA Chair : Jens Knobloch (HZB) : Fundamental SRF research and development

Start	End	THA	Category	Name (Affiliation)	Title
8:30	8:50	THA01	Fundamental SRF R&D	Ming Lu (HZB)	Production of Nb3Sn film on copper substrate by the bronze route and the RF characterization of samples with the quadrupole resonator
8:50	9:10	THA02	Fundamental SRF R&D	Dorothea Fonnesu (INFN-LNL)	Development of Nb3Sn coatings on copper at INFN-LNL
9:10	9:30	THA03	Fundamental SRF R&D	Nathan Sitaraman (Cornell U.)	Improving Quench Fields of Enhanced-Tc Surfaces
9:30	9:50	THA04	Fundamental SRF R&D	Laura Grassellino (FNAL)	Studies as a function of different ALD capping layers on cavity losses for QIS and accelerators
9:50	10:10	THA05	Fundamental SRF R&D	Antonio Bianchi (INFN-LASA)	Understanding Anti-Q-Slope and Q-Slope in SRF Cavities: A Unified Theoretical Framework
10:10	10:30	THA06	Fundamental SRF R&D	Takayuki Kubo (KEK)	Nonequilibrium Corrections and Higgs Mode in Superconducting Devices: Unraveling the Pronounced Anti-Q Slope in High-Frequency regime and Current-Dependent
10:30	11:00	Coffee			

Session THB Chair : Michele Bertucci (INFN-Milano) : SRF Technologies

Start	End	THB	Category	Name (Affiliation)	Title
11:00	11:20	THB01	SRF Technologies	Stéphane Berry (CEA)	Semi-automatic robot assisted, clean assembly of SRF cavity at CEA
11:20	11:40	THB02	SRF Technologies	Laura Popielarski (FRIB/MSU)	Status of Robotics and Automation in the SRF Community and Real Applications
11:40	12:00	THB03	SRF Technologies	Sonia Mathews (CERN)	Cavity Surface Inspection: Automated defect detection using a short focus imaging system
12:00	12:20	THB04	SRF Technologies	John Smedley (SLAC)	Status of the CW SRF gun development for LCLS-II-HE at FRIB
12:20	12:40	THB05	SRF Technologies	Sonja Jaster-Merz (DESY)	Cold Integration of the DESY CW L-band SRF Gun Cavity with Cu Photocathode
12:40	12:55	THB06C	SRF Technologies	Axel Neumann (HZB)	First Beam Commissioning of the bERLinPro Superconducting Radio-Frequency (SRF) Photoelectron Gun
12:55	13:10	THB07C	SRF Technologies	Takashi Ebisawa (QST)	Progress of assembly and installation of LIPAc SRF Cryomodule under the EU–JA Collaborative Framework
13:10	14:30	Lunch			

Session THP : Poster

Start	End	
14:30	17:30	THP

Session Keynote Chair : Michael Kelly (ANL)

Start	End				
17:30	18:30	KEY	Keynote	Hiroyoshi Sakurai (RNC)	Dawn of New Era for Nuclear Physics prevailed by the 2nd generation RI beam accelerator facilities in the world

Friday, September 26

Session FRA Chair : Kenji Saito (FRIB/MSU) : Cavities/ SRF Technologies

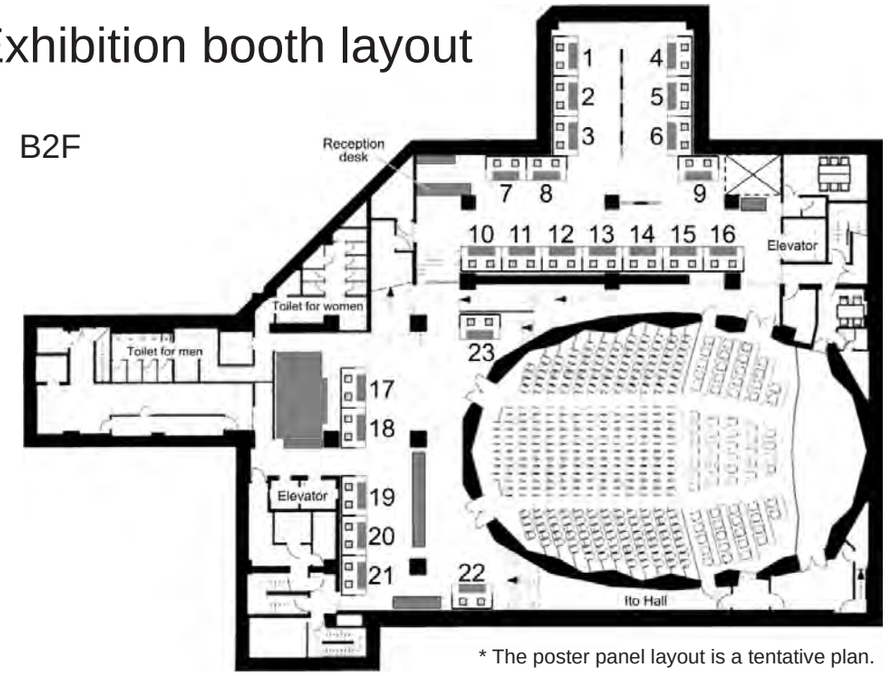
Start	End	FRA	Category	Name (Affiliation)	Title
8:30	8:50	FRA01	Cavities	Jeremiah Holzbauer (FNAL)	PIP-II SRF cavities performance and field emission mitigation strategy
8:50	9:10	FRA02	SRF Technologies	Zachary A. Conway (JLAB)	SRF Technology Challenges for the Electron Ion Collider
9:10	9:30	FRA03	Cavities	Hongtao Hou (SARI-CAS)	Production of 1.3 GHz cavities for SHINE project
9:30	9:50	FRA04	SRF Technologies	Nusair Hasan(FRIB/MSU)	Cryogenics for SRF Accelerator Facilities - Recent Developments and Challenges
9:50	10:10	FRA05	Cavities	Shahnam Gorgi Zadeh (CERN)	SRF cavity development for 400/800 MHz FCC-ee cavities
10:10	10:30	FRA06C	Cavities	Nuria Valverde (CERN)	Test of the first RF Dipole cryomodule for HL-LHC
10:30	11:00	Coffee			

Session FRB Chair : Catherine Madec (CEA/Saclay) : Cavities/ SRF Applications

Start	End	FRB	Category	Name (Affiliation)	Title
11:00	11:20	FRB01	Cavities	Franck Peauger (CERN)	Experimental demonstration of the Slotted Waveguide Elliptical SWELL cavity for high intensity SRF accelerators
11:20	11:40	FRB02	Cavities	Kellen McGee (FNAL)	Development of a Traveling-Wave (TW) structure for high gradients
11:40	12:00	FRB03	SRF Applications	John Vennekate (JLAB)	Overview on Current Activities of Conduction-Cooled SRF Accelerators and their Applications
12:00	12:20	FRB04	SRF Applications	Nicola Pompeo (U. Roma Tre)	Perspectives of superconducting materials in SRF at high fields for large physics experiments
12:20	12:40	FRB05	SRF Applications	Bianca Giaccone (FNAL)/Marc Wenskat (DESY)	Detection of high-f Gravitational Waves using SRF Cavities
12:40	13:40	Closing		Naruhiko Sakamoto, Jens Knobloch, Christian Pira and Daniel Sertore	
14:00		LAB TOUR			

Exhibition booth layout

B2F



* The poster panel layout is a tentative plan.

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(Tabletop exhibit at B1F)
Ailin Vacuum Co., Ltd.

Thank you to all the Exhibitors and Supporters for their contributions to SRF2025.

Social Event

- Welcome Reception (Sep. 21st Sunday)

A Welcome Reception will be held on Sunday September 21, 2025, from 3:00 PM – 6:00 PM. Attendees will be able to complete registration at this time. All attendees are welcome to attend the Student Poster Session from 1:00 PM – 3:00 PM. Registration desk will be open from 12:00 PM.
Location:
Ito International Research Center B2F
The University of Tokyo
7-3-1 Hongo
Bunkyo-ku, Tokyo
Japan

- Banquet (Sep. 24th Wednesday)

A social outing will be held on the afternoon of Wednesday September 24, 2025 from 4:00 PM - 6:00 PM. The excursion will be a Tokyo Bay Symphony Cruise (MODERNA), including the conference dinner
(https://www.symphony-cruise.co.jp , https://dmo-shiba-tokyobay.jp/en/symphony-cruise/).

The cruise ship will depart from Hinode Pier. The close stations are **Hinode Station (U04) on YURIKAMOME Line**, **Hamamatsucho Station (JY28) on Yamanote Line**, and **Daimon Station (E20) on Oedo Line**. It takes 1 min from Hinode Station, 12 min from Hamamatsucho Station, and 15 min from Daimon Station by walk.

※※How to go to Symphony Cruise※※

Route 1: 40 - 50 min.

Venue → Walk (10 min) → Hongo-sanchome (Oedo line, E08) → Oedo line (23 min.) → Shiodome (Oedo line, E19) → YURIKAMOME (4 min.) → Hinode (YURIKAMOME, U04) → Walk (1 min.) → **Symphony Cruise**

Route 2: 40 - 50 min.

Venue → Walk (10 min) → Hongo-sanchome (Oedo line, E08) → Oedo line (25 min) → Daimon (Oedo line, E20) → Walk (15 min.) → **Symphony Cruise**

Route 3: 40 - 50 min.

Venue → Walk (10 min) → Hongo-sanchome (Marunouchi line, M15) → Marunouchi line (7 min.) → Tokyo (Marunouchi line, E17) → Yamanote line (7 min.) → Hamamatsucho (JR, JY28) → Walk (12 min.) → **Symphony Cruise**

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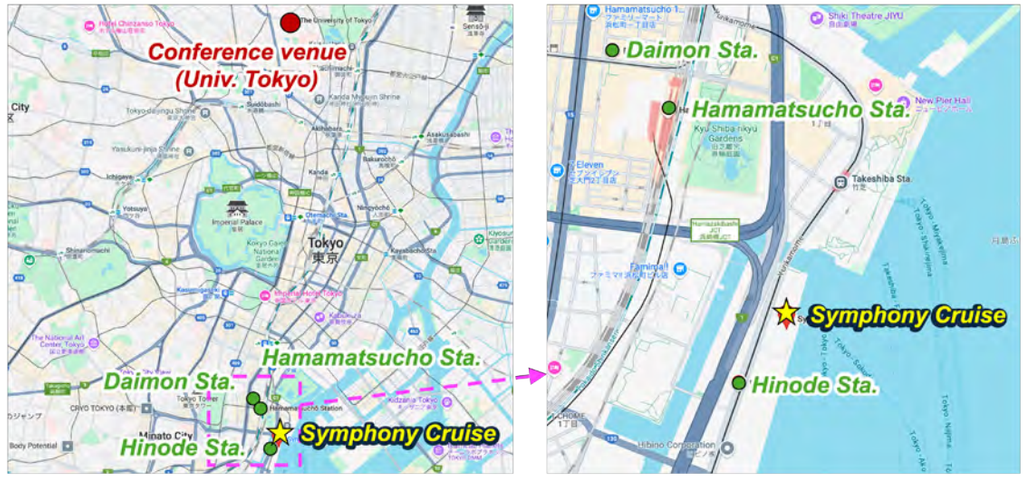
A group photo will be taken from **3:20 PM - 4:00 PM** before the ship leaves.
Participants are kindly requested to bring their banquet tickets and gather at **3:00 PM** at Symphony Cruise.



- Lab tour (Sep. 26th Friday / Pre-registration required)

We invite you to Lab tour at RIKEN Wako campus. The tour will be held on Friday September 26, 2025, from 2:00 PM. In the tour, we will visit two facilities: (1) Linear Accelerator (SRILAC) (2) Cyclotron (SRC) and Fragment Separators (BigRIPS).

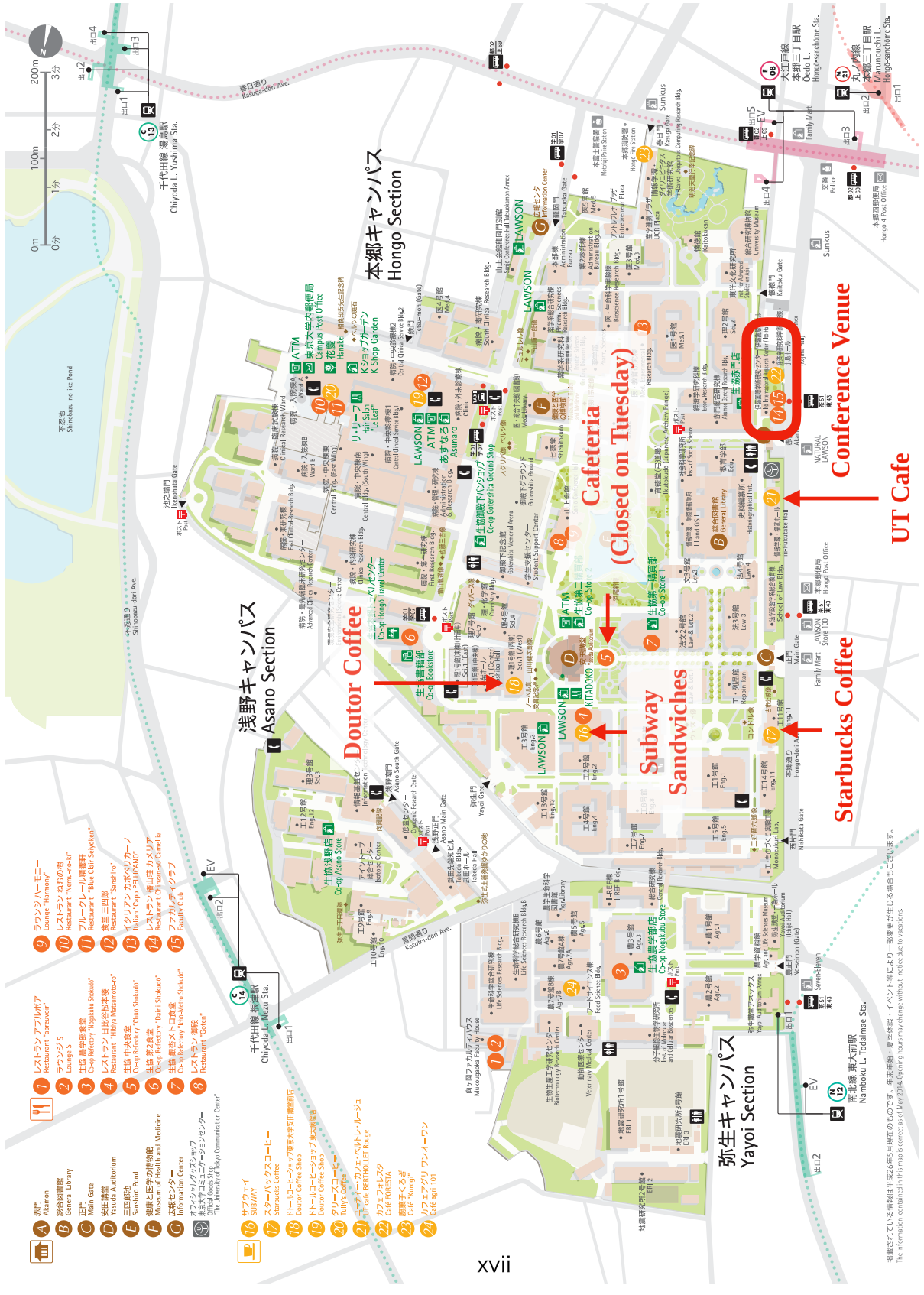
(1) SRILAC

In 2020, SRILAC (Superconducting RIken Linear ACcelerator) achieved beam acceleration for the first time and has since entered the stage of long-term operation, resolving various issues of different sizes. The SRILAC consists of 3 cryomodules based on 10 quarter wave resonators (QWRs) made from bulk niobium sheets and round rods. The superconducting QWR operated at 4.5 K, which was designed for acceleration of low-beta ions, operates at a frequency of 73.0 MHz in continuous wave mode. In the tour, we show SRILAC.

(2) SRC and BigRIPS at RIBF

The Radioactive Isotope Beam Factory (RIBF) is a facility generating unstable nuclei of all elements up to uranium and studying their properties. The Superconducting Ring Cyclotron (SRC) is the largest and most powerful superconducting ring cyclotron in the world (weighing 8,300 tons). The accelerated high intensity ion beams are injected to Fragment Separator called BigRIPS to generate a radioisotope beam for all elements up to uranium with the world-highest intensity. In the tour, we show the SRC and BigRIPS.

Campus Map



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SRF2025 - 22nd International Conference on RF Superconductivity

Sunday 21 September 2025 - Friday 26 September 2025

Ito International Research Center

Book of Abstracts

Monday Oral Session: A - Board: MOA01 / **2**

5 year operation of RIKEN SC-LINAC

Author: Naruhiko Sakamoto[1]

Co-authors: Akito Uchiyama [2]; Hiroshi Imao [2]; Kazunari Yamada [2]; Kazutaka Ozeki [2]; Kenji Suda [2]; Osamu Kamigaito [2]; Takahiro Nishi [2]; Takashi Nagatomo [2]; Tamaki Watanabe [2]

[1] *Nishina Center*

[2] *RIKEN Nishina Center*

Corresponding Author: nsakamot@ribf.riken.jp

The RIKEN superconducting heavy-ion linac, so-called SRILAC, has been successfully operating for almost five years, and continuously deliver a heavy ion beam for a super-heavy-element synthesis experiment by fixing minor and major hardware troubles. The effects of a broken coupler in the early days and four years of operation have resulted in increased X-ray emission levels in several superconducting cavities, which have been successfully corrected by High Power Processing (HPP). Owing to the fine tunings of the control system of LLRF and cryogenic system the availablity more than 99 % has been achieved. This talk will share the experiences and lessons learned from five-year operation with low beta SC-cavities.

Monday Oral Session: A - Board: MOA02 / **27**

Crystallinity in niobium oxides: a pathway for mitigation of two-level system defects in niobium 3D resonator for quantum applications

Author: Thomas Proslier[1]

Co-authors: Fabien Eozénou [2]; Grégoire Jullien [3]; Ivana Curci [1]; Luc Maurice [2]; Patrick Sahuquet [2]; Yasmine Kalboussi [2]

[1] *Université Paris-Saclay*

[2] *Commissariat à l'Energie Atomique*

[3] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

Corresponding Author: prolier@anl.gov

Materials imperfections in Nb-based superconducting quantum circuits—in particular, two-level-system (TLS) defects—are a major source of decoherence, ultimately limiting the performance of quantum computation and sensing. Thus, identifying and understanding the microscopic origin of possible TLS defects in these devices will help developing strategies to eliminate them and is key to superconducting qubit performance improvement. We will report in this presentation, an order of magnitude reduction in two-level system losses in three-dimensional superconducting radio frequency (SRF) niobium resonators by a 10 hour high vacuum (HV) heat treatment at 650 ℃, even after exposure to air and high pressure rinsing (HPR). X-ray photoelectron spectroscopy (XPS) and high-resolution scanning transmission electron microscopy (STEM) reveal an alteration of the native oxide composition re-grown after air exposure and HPR and the creation of nano-scale crystalline oxide regions, which correlates with the measured tenfold quality factor enhancement at low fields of the 1.3 GHz niobium resonator. Tunneling spectroscopy measurements show a pronounced proximity effect that further confirms the presence of metallic layers on the niobium surface.

Monday Oral Session: A - Board: MOA03 / **85**

EIC cabbing cavity RF systems

Author: Subashini De Silva[1]

[1] *Old Dominion University*

Corresponding Author: sdesilva@jlab.org

The Electron-Ion Collider (EIC) being implemented at Brookhaven National Laboratory (BNL) in partnership with Thomas Jefferson National Accelerator Facility (JLab) is designed to collide electrons and protons/Heavy Ions with energies of 5-18 GeV, 2.5 A in the Electron Storage Ring (ESR) and the 41 to 275 GeV/u, 1 A in the Hadron Storage Ring (HSR). The interaction region with a crossing angle of 25 mrad relies on several Crabbing Cavity RF Systems operating at 197 MHz and 394 MHz. All the crabbing systems are designed with superconducting rf-dipole type cavities where the HSR will include both 197 MHz and 394 MHz crabbing cavities, whereas ESR will include only 394 MHz crabbing cavities. In this presentation, we will review the complexities and challenges of the EIC crabbing systems.

Monday Oral Session: A - Board: MOA04 / **42**

Specification, design, production and test schedule of cryomodule for SRF 5-year plan (MEXT-ATD) at KEK by global collaboration for ILC technology network

Author: Yasuchika Yamamoto[1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: yasuchika.yamamoto@kek.jp

A five-year project (MEXT advanced Accelerator element Technology Development (MEXT-ATD)) funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) began at KEK in FY2023. The goal is to manufacture, construct and test a cryomodule (CM) that satisfies the ILC (International Linear Collider Project) specifications and conduct cooling tests. The MEXT-ATD program is closely related to the ILC Technology Network (ITN). Many SRF experts from Europe and Korea are already joining to contribute to 9-cell cavity production in each region. The 3D model of the cryomodule will be based on the Type-4 CM adopted in the Technical Design Report (TDR) published in 2013, moreover will also reflect the latest technology and experience obtained from the construction and operation of the European XFEL in Europe and LCLS-II in the United States since the TDR. In addition, in anticipation of future prospects, it has been decided that the design and production of every cavity and CM will be based on the refrigeration regulations of the High Pressure Gas Safety (HPGS) Act in Japan. In this presentation, the basic specifications and design of the cryomodule as well as the overall manufacturing/test schedule and recent progress will be reported in detailed.

Funding Agency:

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Monday Oral Session: A - Board: MOA05 / **93**

Recent advances in 3D SRF cavity-based quantum computing facility at the Fermilab SQMS Center

Author: Alexander Romanenko[1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: aroman@fnal.gov

This talk will describe the most recent advances and progress in building an SRF cavity-based quantum computing facility at the Fermilab SQMS center. Several technical challenges had been successfully overcome to preserve the highest quality factors of SRF cavities in the presence of the sapphire chip holding the transmon qubit inside the cavity. The record values of the attained multicell cavity (2-cell, 9-cell)-qubit systems will be presented, as well as a variety of quantum operations realized with such systems, including the generation of large Fock states, coherent states, entangled mode-mode states etc. The quantum algorithms and computational problems being implemented on this 3D SQMS QPUs will be discussed as well.

Monday Oral Session: B - Board: MOB01 / **31**

Commissioning of ESS superconducting linac

Author: Cecilia Maiano[1]

[1] *European Spallation Source*

Corresponding Author: cecilia.maiano@ess.eu

The SCL is an in kind contribution to ESS by IJCLAB (spoke cavities and cryomodules), INFN (Medium Beta Cavities), STFC (High Beta cavities) and CEA (all elliptical cryomodule assembly). Spoke cryomodules have been tested at FREIA facility in Uppsala (Sweden) and elliptical cryomodules have been tested at the ESS Test Stand 2 in Lund. The installation of 27 cryomodules (13 spokes, 9 medium beta and 5 high beta elliptical) was completed in summer 2024, providing a 2 MW beam power capability on a neutron production target for the first operation phase of the facility. The ESS superconducting linac cool down to 4 K started in December 2024, followed by the non-on resonance cold coupler conditioning of all 82 superconducting cavity couplers (26 spoke, 36 medium beta and 20 high beta elliptical). Stable 2 K conditions were reached in January 2025, followed by the tuning to resonance and the start of cavity conditioning process to nominal operation parameters. The preparation of cavities for stable beam operation is currently ongoing, after recovering from infrastructure outages that resulted in cryoplant failure and full unintentional warmup cycle. Beam operation, first in the normalconductiong front end and then to the temporary beam dump will start on March 19th. In the talk we summarize the experience of cryomodules commissioning in the ESS linac and compare tot the site acceptance test of the cryomodules and the factory acceptance tests of the cavities at the in kind partners.

Monday Oral Session: B - Board: MOB02 / **86**

LCLS-II operation status and the LCLSII_HE upgrade

Author: Lauren Alsberg[1]

[1] *SLAC National Accelerator Laboratory*

Corresponding Author: alsberg@slac.stanford.edu

The Linac Coherent Light Source superconducting linac (LCLS-SC) at SLAC National Accelerator Laboratory, built during the LCLS-II project, has now been in operation for the past three years, with user experimental delivery commencing in 2024. In 2026, the LCLS-II-HE project will add 23 additional 1.3 GHz cryomodules, bringing the LCLS-SC maximum electron beam energy from 4 GeV to 8 GeV. This talk will provide an overview of operational experiences, challenges, and performance analysis of the SRF cavities and associated systems during the first few years of LCLS-SC operation, performance improvements in preparation for LCLS-II-HE, as well as the LCLS-II-HE cryomodule performance test results.

Monday Oral Session: B - Board: MOB03 / **65**

FRIB operation, status of power upgrade, and R&D for FRIB400

Author: Ting Xu[1]

Co-authors: Alexander Plastun [2]; Andreas Stolz [2]; Bryan Tousignant [1]; Dan Morris [1]; Fabio Casagrande [2]; Guillaume Machicoane [2]; Hiroyuki Ao [2]; Jie Wei [2]; John Wenstrom [1]; Junwei Guo [2]; Kenji Saito [2]; Kent Holland [2]; Kyle Elliott [1]; Laura Popielarski [2]; Nusair Hasan [2]; Peter Ostroumov [2]; Qiang Zhao [2]; Rao Ganni [2]; Sang-hoon Kim [2]; Shen Zhao [2]; Steven Lidia [2]; Takuji Kanemura [2]; Taro Konomi [2]; Tomofumi Maruta [2]; Walter Hartung [2]; Wei Chang [2]; Xiaoji Du [2]; Xing Rao [2]; Yoonhyuck Choi [2]

[1] *Facility for Rare Isotope Beams*

[2] *Michigan State University*

Corresponding Author: xuti@frib.msu.edu

FRIB is the first heavy-ion accelerator facility to deploy a large number of Half-Wave Resonators (220 HWRs) and operate at 2 K in its superconducting drive linac. As of today, FRIB delivered the world's highest uranium beam power (>18 kW) on target and will continue its power ramp-up in the next few years in parallel to support user science program. The technologies that have sustained the establishment of the FRIB facility and beam power ramp-up include large-scale superconducting RF, superconducting magnets, liquid metal charge stripping, and high-power targetry. This talk summarizes the current operational experience with these technologies, the plan to ramp up power to the full design power of 200 kW, and the R&D activities preparing for a 400 MeV energy upgrade in the near future.

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Monday Oral Session: B - Board: MOB04 / **44**

Status of the SRF activities for the SHINE project

Author: Jinfang Chen[1]

[1] *Shanghai Advanced Research Institute*

Corresponding Author: chenjinfang@sari.ac.cn

Mass production of cavities and cryomodules for SHINE project are underway. Up to now, more than 50 mid-T baked cavities and 100 N-doped cavities have been vertical tested. Most of them have been assembled into cryomodules and tested, achieving high Q and quite high gradient. Two special cryomodules (CMs) for SHINE injector have been commissioned, reached their designed voltage. High-Q CMs are gradually installed into the Linac section. Two 3.9 GHz CMs have been assembled and tested, achieved excellent performance. This presentation will cover the progress of production, the performance of cavities and CMs, the upgrade of SRF infrastructures and so on.

Monday Oral Session: B - Board: MOB05 / **8**

Commissioning of the first HElmholtz LInear ACcelerators (HELIAC) cryomodule with heavy ion beam

Author: Maksym Miski-Oglu[1]

Co-authors: Florian Dziuba [2]; Julian List [2]; Simon Lauber [2]; Thorsten Kuerzeder [1]; Winfried Barth [1]; Stepan Yaramyshev [1]; Viktor Gettmann [1]; Uwe Scheeler [1]; Hartmut Vormann [1]

[1] *GSI Helmholtz Centre for Heavy Ion Research*

[2] *Helmholtz Institute Mainz*

Corresponding Author: m.miskioglu@gsi.de

The superconducting heavy ion HELmholtz LInear ACcelerator (HELIAC) is designed to meet the needs of the Super Heavy Element (SHE) research and material sciences user programs at GSI in Darmstadt. The HELIAC is planned for construction at GSI in Darmstadt. The beam energy can be varied smoothly between 3.5 and 7.3 MeV/u, with an average current of up to 1 emA and a duty cycle of 100 %. Recently, the first cryomodule CM1, was fully commissioned and tested w/o beam. CM1 comprises three Crossbar H-mode (CH)-type accelerator cavities, a CH-rebuncher, and two superconducting solenoid lenses. Following the commissioning of the cryogenic supply and the RF-systems, successful beam tests were conducted at the end of 2023 and mid of 2024. A helium as well as an argon ion beam was successfully accelerated to the design energy. The beam energy could be varied continuously between 1.3 and 3.1 MeV/u without any significant particle losses being measured in the cryomodule. This contribution covers the construction and commissioning of the first HELIAC cryomodule and the results of the beam test campaign.

Monday Oral Session: B - Board: MOB06 / **7**

5 years of SPIRAL2 LINAC operation: cryogenic and superconducting RF aspects

Author: Muhammad Aburas[1]

Co-authors: Adnan Ghribi [1]; Jean-François Leyge [1]; Marco Di Giacomo [1]; Pierre-Emmanuel Bernaudin [1]

[1] *Grand Accélérateur Nat. d'Ions Lourds*

Corresponding Author: muhammad.aburas@ganil.fr

The superconductor linear accelerator LINAC of SPIRAL2 at the GANIL facility is in operation since October 2019. The 26 superconducting quarter wave resonators (QWR) of the LINAC are integrated into 19 cryostats and cooled down at 4 K by a dedicated refrigeration system. These superconducting cavities are operated at a nominal gradient of 6.5 MV/m but most of the cavities can be operated up to 8 MV/m. One of the 26 cavities shows abnormal energy dissipation at medium and high RF gradient.

In this paper, we will present the evolution of the superconducting cavities and the main issues that happened to the superconducting LINAC and its cryogenic system during the last six years and their effects on the beam schedule.

Monday Poster Session - Board: MOP01 / **202**

HOM study for CEPC cavities: HOM damping and recent developments

Author: Hongjuan ZHENG[1]

Co-authors: Jie Gao [2]; Jiyuan Zhai [1]

[1] *Institute of High Energy Physics*

[2] *Chinese Academy of Sciences*

Corresponding Author: zhenghj@ihep.ac.cn

CEPC is engineered to function in four distinct operational modes (Higgs, W, Z-pole, and t-tbar), supporting a broad spectrum of beam parameters. The collider's beam energy ranges from 45.5 to 180 GeV, with a beam current varying from 5.6 mA to 1.4 A, and a synchrotron radiation (SR) power output ranging from 30 to 50 MW. The collider is a double-ring with shared cavities for Higgs operation and separate cavities for W and Z operations. The higher order modes (HOM) excited by the intense beam bunches must be damped to avoid additional cryogenic loss and multi-bunch instabilities. In this paper, the impedance, HOM damping and HOM power requirements for the CEPC collider ring are given. This HOM power limit and the fast-growing longitudinal coupled-bunch instabilities (CBI) driven by both the fundamental and higher order modes impedance of the RF cavities determine to a large extent the highest beam current and luminosity obtainable in the Z mode. The prototypes of HOM coupler have been fabricated and tested on the 650 MHz 2-cell cavity. The mechanical, RF, and cryogenic performance of the higher-order mode coupler has been verified. A full-size cryomodule with 6 cavities and 12 HOM couplers is currently under development. Finally, the deep suppression of HOMs with high-power extraction, and the associated technical challenges were discussed.

Monday Poster Session - Board: MOP02 / **271**

CEPC superconducting RF system EDR design and R&D

Author: Jiyuan Zhai[1]

Co-authors: Baiqi Liu [1]; Chao Dong [1]; Fanbo Meng [1]; Hongjuan ZHENG [1]; Mei Li [1]; Miaofu Xu [1]; Peng Sha [1]; Rui Ge [1]; Xu Chen [1]; Zheng Mi [2]; song jin [1]

[1] *Institute of High Energy Physics*

[2] *Chinese Academy of Sciences*

Corresponding Author: zhaijy@ihep.ac.cn

The CEPC (Circular Electron-Positron Collider) is a 100-kilometer circular collider designed to operate at center-of-mass energies ranging from 90 GeV to 360 GeV, with the primary physics program targeting Z and W bosons, Higgs bosons, and top-quark pair (ttbar) production. Following the publication of its Technical Design Report (TDR) in 2024, the project has now entered the Engineering Design Report (EDR) phase. This contribution outlines the EDR design of the CEPC's Superconducting Radiofrequency (SRF) system, along with the associated R&D challenges and recent progress.

During the EDR phase, the SRF system's primary objective is to develop SRF cryomodules for the first operational stage of the CEPC. A key milestone will be a full-scale 650 MHz cryomodule prototype for the collider ring to validate the stable operation using an 800 kW continuous-wave (CW) klystron and the Low-Level Radio Frequency (LLRF) control system. Additionally, preparations for mass-production of 650 MHz and 1.3 GHz cavities and cryomodules are underway aligned with China's ongoing large-scale SRF projects.

Monday Poster Session - Board: MOP03 / **212**

Operational status and experience of the TLS CESR-B type SRF module

Author: Chih Hung Lo[1]

Co-authors: Chao-Hui Huang [1]; Chaoen Wang [1]; Fu-Tsai Chung [1]; Ling-Jhen Chen [1]; Mei-Hsia Chang [1]; Meng-Shu Yeh [1]; Ming-Chyuan Lin [1]; Shian-Wen Chang [1]; Yi-Ta Li [1]; Zong-Kai Liu [1]

[1] *National Synchrotron Radiation Research Center*

Corresponding Author: lo.ch@nsrrc.org.tw

Taiwan Light Source (TLS) is a third-generation synchrotron light source located at NSRRC in Taiwan, operating at an electron energy of 1.5 GeV. The original RF system of TLS utilized two normal-conducting Doris cavities. In 2005, these were replaced with a single CESR-B type superconducting RF (SRF) module, which significantly improved the system's stability and enabled an increase in the operating beam current to 360 mA. This report describes the operational performance of the SRF module over more than 20 years, including statistical records, performance monitoring, and major operational issues along with their solutions. The status of the spare SRF module is also discussed in this report.

Monday Poster Session - Board: MOP04 / **140**

Commissioning plans for the CSNS-II superconducting linac

Author: Jun Peng[1]

Co-authors: Yanliang Han [2]; Huachang Liu [2]; Xinyuan Feng [2]; Zhiping Li [2]

[1] *Institute of High Energy Physics*

[2] *China Spallation Neutron Source; Institute of High Energy Physics*

Corresponding Author: pengjun@ihep.ac.cn

The power upgrade project of the China Spallation Neutron Source(CSNS-II) was officially launched in 2024. It will upgrade the accelerator complex five times its current beam power capability, from 100 kW to 500 kW. A key component of the project is the superconducting linac(SCL), designed to accelerate an H- beam of 43 mA peak current from 80 MeV to 300 MeV. The SCL is composed of two families of cavities: 324 MHz double-spoke cavities and 648MHz elliptical cavities. This article describes the commissioning strategy plans for the SCL, with a focus on techniques for establishing RF setpoints and implementing rapid fault recovery in the event of cavity or subsystem failures. Additionally, other critical requirements, such as beam matching and steering approaches are discussed as well.

Monday Poster Session - Board: MOP06 / **240**

Upgrade of E2.0cryogenic plant

Author: Marco Modica[1]

Co-authors: Alessandro Fabris [1]; Emanuel Karantzoulis [1]; Simone Di Mitri [1]; Stefano Krecic [1]; alessandro Carniel [1]; pietro zupancich [1]

[1] *Elettra-Sincrotrone Trieste S.C.p.A.*

Corresponding Author: marco.modica@elettra.eu

As part of the upgrade of the Elettra synchrotron ring to Elettra 2.0, an upgrade and expansion of the helium liquefaction plant is also planned. The current cryogenic system is based on a Kaeser He compressor and a Helial 1000 cold box liquefier/refrigerator, with a Siemens S7-00 PLC-based control system, currently connected exclusively to the superconducting third harmonic cavity (S3HC).

The upgraded system will continue to provide cooling for the S3HC, but will also supply liquid helium to users and provide cryogenic support for the superconducting wiggler (SCW). A complete renewal of the control system is underway, transitioning from the obsolete and unsupported Siemens S7-00 PLC to the S7-1500 series.

A helium recovery and re-liquefaction system is planned both for the SCW and for the beamlines that require liquid helium for experimental activities.

This paper presents the current status of the cryogenic plant upgrade project, along with its economic and environmental impact.

Monday Poster Session - Board: MOP07 / **156**

Beam dynamics studies of cavity failures for the initial operation phase of the ESS superconducting linac

Author: Bruce Yee-Rendon[1]

Co-authors: Fujio Maekawa [1]; Jun Tamura [1]; Mamad Eshraqi [2]; Natalia Milas [2]; Ryoichi Miyamoto [2]; Shin-ichiro Meigo [1]; Yasuhiro Kondo [1]

[1] *Japan Atomic Energy Agency*

[2] *European Spallation Source*

Corresponding Author: byee@post.j-parc.jp

The European Spallation Source (ESS) superconducting proton linac is currently undergoing commissioning. During the initial operation phase, the final beam energy will be about 800 MeV, reaching a 2 MW power. High reliability and availability are crucial for the success of the ESS science programs and thus operations will be maintained even with failures of main linac components such as cavities and quadrupoles, as long as ~50 % of the intended power can be achieved. To this end, we developed beam optics strategies to address failures in the cavities of the superconducting linac. Due to the constraints in the RF cavity amplitudes, we implemented a modified version of standard cavity compensation techniques. The results indicated that this strategy enables beam recovery that meets the beam quality specifications, thereby enhancing the availability of the ESS linac.

Monday Poster Session - Board: MOP08 / **141**

Optimization of several operating parameters to increase the beam delivery time at the European XFEL

Author: Vladimir Vogel (Fogel)[1]

Co-authors: Chris Christou [1]; Christian Schmidt [1]; Denis Kostin [1]; Julien Branlard [1]; Marco Diomede [1]; Nicholas Walker [1]; Valeri Ayvazyan [1]

[1] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Author: vladimir.vogel@desy.de

Currently, the pulsed linac at EuXFEL, operated at DESY, according to the design parameters can deliver up to 2700 electron bunches during beam delivery time of 600 µs inside of RF flat-top time of 650 µs. The user community is interested to have more photon pulses which can be done only by increasing RF flat-top length. The RF pulse length at the linac is limited by several factors, primarily the RF pulse length in the existing photoinjector. The new RF photoinjector, currently under development and testing, will enable beam pulses of up to 800µs. The second limiting factor could be the stability of the RF power sources, the klystrons, which must handle longer high-voltage and RF pulses. Another very important part are the accelerating cavities and RF fundamental couplers, which must handle increasing power during cavity filling and a longer RF flat-top time. Initial investigations into extending the RF flat-top length began in 2022. Recently, various measures have been developed and implemented to increase the RF flat-top length while keeping power consumption low without compromising linac performance. These include optimizing the high-voltage shape of the klystron, the high-power RF shape, and the coupling factors of the accelerating cavities. The latest results from development and tests of several RF stations with a beam delivery time of 800 µs are presented.

Monday Poster Session - Board: MOP09 / **3**

Dynamics issues and challenges of superconducting triple RF systems in future-synchrotron light sources

Author: Tianlong He[1]

Co-authors: Jincheng Xiao [1]; Weimin Li [1]

[1] *University of Science and Technology of China*

Corresponding Author: htlong@ustc.edu.cn

In new-generation synchrotron light sources, triple-radio-frequency (triple-RF) systems are proposed to meet larger bunch lengthening requirements and enable specific longitudinal injection conditions. In this talk, we will present beam dynamics analysis for the superconducting triple-RF system designed for the Hefei Advanced Light Facility (HALF) storage ring. We will demonstrate that a particular beam instability imposes stringent requirements on the R/Q values of the triple-RF system, mainly for the higher harmonic cavities. For HALF, our findings reveal that the R/Q values of the two higher harmonic cavities need to be reduced to approximately 10 or below to achieve the optimal bunch lengthening. Such exceptionally low R/Q values pose new issues and challenges for the design of higher harmonic cavities.

Monday Poster Session - Board: MOP10 / **197**

France-Japan collaboration for high-Q / high-G SRF cavities

Author: Akira Miyazaki[1]

[1] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

Corresponding Author: akira.miyazaki@cern.ch

Highly performing SRF cavities are of general importance for multiple future projects and can only be realized in international collaborations. One crucial issue is standardization of parameters during chemical etching, heat treatment, and vertical tests. We have identified tiny differences in locally defined parameters in the laboratories. In parallel to collaborative initiative within European laboratories as well as between American and French institutions, we consolidate the collaboration between France and Japan. We are currently working on a 1-cell 1.3 GHz cavity to systematically compare the vacuum furnaces in IJCLab and KEK as well as vertical tests in CEA and KEK. Our studies include mid-T baking, high-temperature annealing, low-temperature baking, and the magnetic field sensitivity. In this contribution, we summarize the global scope of the collaboration, comparison of furnaces, and vertical tests results.

Monday Poster Session - Board: MOP11 / **74**

Early exploration of zirconium doping SRF cavities with chemical vapor deposition

Author: Alexis Grassl[1]

Co-author: Matthias Liepe [1]

[1] *Cornell University*

Corresponding Author: ag2649@cornell.edu

The introduction of zirconium to niobium SRF cavities suggests a promising alloy with lower RF losses, higher critical magnetic fields, and a higher endurance to gradients. However, difficulties in fabrication of a ZrNb alloy, especially on the irregular surface of SRF cavities, have slowed the applicatory study of this potential improvement. We utilize a newly commissioned chemical vapor deposition system to fabricate this alloy with minimal surface defects on irregular surfaces. We present the initial results of this method's effectiveness with surface characterization methods.

Monday Poster Session - Board: MOP14 / **124**

High Q –high G study on single cell medium grain niobium cavities

Author: Ashish Kumar[1]

Co-authors: Hayato Ito [1]; Kensei Umemori [1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: ashish.kumar@kek.jp

Medium Grain Niobium (MG Nb) is a cost-effective material compared to Fine grain Nb (FG Nb) that has isotropic mechanical properties, and can clear the high-pressure gas safety criteria for a 1.3 GHz

9-Cell jacketed Tesla cavity. At KEK, various high Q –high G surface treatments have been applied to the 1-Cell MG Nb cavities and its performance has been measured via vertical tests, with and without trapped flux. It has been observed that the performance of these cavities are on par with FG Nb cavities for standard, 2-step and Mid-T furnace baking. Moreover, the flux expulsion of the single cell MG Nb cavity has been studied at 800 and 900 ℃ annealing.

Monday Poster Session - Board: MOP15 / **68**

Ab initio investigation of surface passivation coatings to suppress Nb oxide formation

Author: Cristobal Mendez[1]

Co-authors: Nathan Sitaraman [1]; Sadie Seddon-Stettler [1]; Matthias Liepe [1]; Tomás Arias [1]

[1] *Cornell University*

Corresponding Author: crismendezv@gmail.com

Niobium-based superconducting radio-frequency (SRF) cavities are crucial for particle accelerators, yet their performance is limited by native niobium oxide formation, which contributes significantly to increased residual surface resistance. This oxidation challenge is similarly critical in superconducting quantum circuits, where niobium oxide layers adversely impact coherence times and device stability. To address these issues, we present a first-principles density functional theory (DFT) study exploring surface passivation strategies using noble metals (Au, Pt, Pd) and stable oxide coatings (Al_2O_3, ZrO_2) on Nb substrates. Our calculations systematically assess the thermodynamic stability, interface energies, and electronic interactions at Nb–coating interfaces. Results identify several candidate materials exhibiting superior stability compared to native niobium oxide, potentially suppressing its formation. By effectively passivating the Nb surface, these coatings promise significant reductions in residual resistance for SRF cavities and enhanced coherence for superconducting qubits. These insights offer theoretical guidance for experimental implementation, contributing to improved performance across superconducting technologies.

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Monday Poster Session - Board: MOP16 / **129**

Magnetic flux expulsion lens: concept and measurements

Author: Daniel Turner[1]

Co-author: Alick Macpherson [1]

[1] *European Organization for Nuclear Research*

Corresponding Author: daniel.andrew.turner@cern.ch

The trapping of magnetic flux during the transition of a superconducting radio frequency (SRF) cavity can substantially increase RF dissipation in the cavity walls, leading to a reduction in Q0, that in turn can increase cryogenic costs. The impact of trapped magnetic flux can be reduced by either suppressing the ambient magnetic field or by limiting/removing the influence of pinning sites in the

material. The former involves custom engineering solutions, the latter requires an understanding of the magnetic response of the cavity material. To quantify magnetic trapping of cavity material, a magnetic flux lens (MFL) has been developed at CERN. This device is based on topological conduction cooling for small samples, allowing repeatable cooling dynamics to analyse the spatial thermal gradients and velocity of the superconducting wavefront. Each thermal cycle investigates the magnetic flux trapping on a macroscopic scale. A program of quantitative measurements of magnetic flux expulsion on flat samples has been used to assess the expulsion efficiency of bulk Nb, cold worked bulk Nb with and without heat treatments, sputtered Nb on Cu, sputtered Nb3Sn on Cu and SIS multilayer structures. An overview of the results are reported. Our concept offers a stand alone means to control the dynamics of the Meissner effect, and the MFL can be used both for material qualification and for investigation of the magneto-thermal behaviour of the RF layer.

Monday Poster Session - Board: MOP17 / **299**

In-situ HRTEM monitoring of oxide layer decomposition and lattice defect evolution on Nb during Medium-T Baking

Author: Yuan He[1]

Co-authors: Didi Luo [1]; Teng Tan [2]; Shantong Chen [2]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Institute of Modern Physics*

Corresponding Author: hey@impcas.ac.cn

Medium-temperature baking (Medium-T Baking) has emerged as a key technique for enhancing SRF cavity performance, with multiple studies attributing its efficacy to oxide decomposition and oxygen diffusion. In-situ high-resolution transmission electron microscopy (HRTEM) enables real-time, atomic-scale visualization of dynamic structural changes, providing an ideal platform for probing Nb oxide layer dynamics during baking.

Our previous in-situ HRTEM measurements at 350 ℃ heating showed emergent ‘white dots’ and local contrast variations that revealed nanoscale lattice transformations. Recently, we utilized on-site vacuum storage to avoid cross-section sample oxidation post-FIB processing, which enabled us to single out the oxide layer for both HRTEM and energy-dispersive X-ray spectroscopy (EDS) to obtain definitive evidence of its decomposition during heating. We also detected interstitial oxygen diffusion-induced lattice defects via HRTEM.

Preliminary results showed that the observed defects may enhance cavity performance, and further vertical tests are underway to fully elucidate the underlying mechanisms.

Monday Poster Session - Board: MOP18 / **226**

Nb3Sn coatings on copper at INFN-LNL

Author: Dorothea Fonnesu[1]

Co-authors: Alex Battistello [2]; Cristian Pira [1]; Davide Ford [2]; Eduard Chyhyrynets [1]; Fabrizio Stivanello [1]; Flavio Pasquato [2]; Giorgio Keppel [1]; Matteo Lazzari [2]; Michele Lollo [2]; Oscar Azzolini [2]; Thomas Bortolami [2]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro*

Corresponding Author: fonnesu@infn.it

The successful development of Nb3Sn/Cu coatings for the SRF cavities of next generation particle accelerators would allow for the operation of the SRF system at 4.5 K, resulting in a reduction of the needed cryogenic power by a factor 3 with respect to what normally needed for bulk Nb cavities, operated at 2 K. In the framework of I.FAST and ISAS collaborations, an optimized recipe for Nb3Sn films deposited via DCMS has been established on small samples at INFN-LNL and is discussed in this work. Films with a Tc ≥ 17 K at deposition temperatures ≤ 650 ℃ on Cu substrate pre-coated with a 30-micron thick buffer layer of Nb have been successfully produced. The same deposition recipe is RF validated on bulk Nb QPR sample, with the results being also discussed in this work. A surface resistance of 23 nΩ at 4.5 K (at 20 mT, 417 MHz, with quench field ~ 70 mT) is measured, which is about 5 times larger than the baseline specifications for the LHC Nb/Cu cavities and already fulfills the requirements for the FCC-ee. Finally, the expected challenges toward the scalability of the coating recipe to an elliptical cavity prototype are discussed.

Monday Poster Session - Board: MOP19 / **342**

ELBE SRF gun –the most advanced source of its kind

Author: Andre Arnold[1]

Co-authors: Adrian Hoffmann [1]; Anton Ryzhov [1]; Gianluigi Ciovati [2]; Ingo Will [3]; J. Michael Klopf [1]; Jochen Teichert [1]; John Vennekate [2]; Petr Murcek [1]; Rico Schurig [1]; Rong Xiang [1]

[1] *Helmholtz-Zentrum Dresden-Rossendorf*

[2] *Thomas Jefferson National Accelerator Facility*

[3] *Max-Born-Institute for Nonlinear Optics and Short Pulse Spectroscopy*

Corresponding Author: a.arnold@hzdr.de

At the electron accelerator for beams with high brilliance and low emittance (ELBE), the second version of a superconducting radio-frequency (SRF) photoinjector was brought into operation in 2014. After a period of commissioning, a gradual transfer to routine operation took place in 2017, so that now up to 1800h of user beam are generated every year. In addition to this standard mode with a few tens of microamperes, another important milestone was achieved recently. An average current of 1 mA at a repetition rate of 13 MHz was generated and further accelerated to almost 30 MeV by the ELBE LINAC. After guiding the beam to one of the IR-FELs, lasing was easily achieved and even a very sensitive user experiment was conducted. This is particularly important with regard to the successor of the ELBE accelerator called DALI, which is planned to be fed by an SRF gun with a high average current as well. The contribution presents the most important steps for achieving the full beam current and summarizes related measurement results and findings. No fundamental difficulties were identified.

Monday Poster Session - Board: MOP20 / **76**

Initial results for CVD based growth of Nb_3Sn

Author: Gabriel Gaitan[1]

Co-authors: Alexis Grassl [1]; Caleb Middleton [1]; Matthias Liepe [1]; Nathan Sitaraman [1]

[1] *Cornell University*

Corresponding Author: gg465@cornell.edu

Niobium-3 tin (Nb_3Sn) is a promising material for next-generation superconducting RF cavities due to its high critical temperature and high theoretical field limit. There is currently significant worldwide effort aiming to improve Nb_3Sn growth to push this material to its ultimate performance limits. In this paper, we present the first results of deposition of Sn on different Nb samples in different orientations in our Chemical Vapor Deposition (CVD) system. We discuss imaging results and the stoichiometry achieved for Nb_3Sn coupons. We compare the films' deposition uniformity with expected results from flow simulations. We describe the parameters used in the coating and future steps towards coating a 2.6 GHz cavity in our CVD system. We also discuss current technical limitations in the CVD process and potential alternative tin precursors to improve coating uniformity and stoichiometry.

Funding Agency:

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Monday Poster Session - Board: MOP21 / **73**

Commissioning of chemical vapor deposition system for superconducting thin films

Author: Alexis Grassl[1]

Co-authors: Adam Holic [1]; Blake Wendland [1]; Caleb Middleton [1]; Gabriel Gaitan [1]; Greg Kulina [1]; James Sears [1]; Matthias Liepe [1]; Peter Quigley [1]; Will Howes [1]

[1] *Cornell University*

Corresponding Author: ag2649@cornell.edu

Next-generation, thin-film surfaces employing Nb3Sn, NbN, NbTiN, or other compound superconductors are essential for reaching enhanced RF performance levels in SRF cavities. However, optimized, advanced deposition processes are required to enable high-quality films of such materials on large and complex-shaped cavities. For this purpose, Cornell University developed and commissioned a chemical vapor deposition (CVD) system that facilitates coating on complicated geometries with a high deposition rate. This system is based on a high-temperature tube furnace with a high-vacuum, gas, and precursor delivery system. Here, we present the commissioned system with the control aspects and safety considerations addressed and the materials we are interested in growing.

Footnotes:

Both G. Gaitan and A. Grassl are primary authors of this contribution.

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Monday Poster Session - Board: MOP22 / **201**

Progress in Nb3Sn vapor diffusion method for single-cell cavities at KEK

Author: Hayato Ito[1]

Co-authors: Tomohiro Yamada [1]; Kensei Umemori [1]; Hiroshi Sakai [1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: hayato.ito@kek.jp

Nb3Sn SRF cavities have attracted increasing attention as a candidate for next-generation accelerators due to their potential to achieve high Q-values even at 4.2 K, enabling operation with conduction cooling. Since 2019, KEK has been developing Nb3Sn single-cell cavities via the vapor diffusion method using Sn and SnCl2 sources. In parallel, a dedicated small-scale coating system was constructed to promote systematic investigations using planar samples. This contribution presents recent progress in both single-cell cavity coatings and sample-based investigations. Notably, our best-performing cavity achieved an accelerating gradient of 17.5 MV/m with a Q-value of 1.2×10^{10} at 5 MV/m and 4.2 K. Through systematic trials, we are beginning to clarify how coating parameters—such as source amount and heating duration—under our furnace environment relate to cavity performance. In addition, sample studies have provided intriguing insights into how variations in coating conditions affect the resulting film quality. These insights are being used to refine the coating protocol in the large cavity furnace.

Funding Agency:

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Monday Poster Session - Board: MOP23 / **180**

Strength evaluation of high-purity niobium single crystals considering crystal orientation

Author: Masashi Yamanaka[1]

Co-authors: Hiroaki Umezawa [2]; Naoshi Nishida [3]

[1] *High Energy Accelerator Research Organization*

[2] *The Graduate University for Advanced Studies, SOKENDAI*

[3] *Tokyo Denkai Co., Ltd.*

Corresponding Author: masashi.yamanaka@kek.jp

The relationship between crystal orientation and the strength of single-crystal niobium was evaluated. First, several single-crystal blocks were cut from a niobium ingot, and bar tensile testing specimens were taken from each block. In previous studies, a niobium ingot was sliced to produce a disk, from which a small single-crystal flat specimen was cut; however, this time, round bar specimens were used. This distinction is one of the features of this study. The longitudinal orientation of each test specimen was measured using EBSD, after which tensile tests were performed. The Schmidt factor was calculated, assuming a {110} slip system, revealing a correlation with the 0.2 % proof stress that satisfies Schmidt's law. The CRSS was 36.5 MPa. Next, a method was developed to extract test specimens with orientations that maximized and minimized the Schmidt factor. Test specimens targeting (1 1 1) and (9 2 20) were successfully produced. As anticipated, the 0.2 % proof stress was maximized and minimized during tensile tests. Based on these findings, we examined the derivation of the minimum strength required for designing LG niobium cavities.

Monday Poster Session - Board: MOP24 / **176**

Design, fabrication and concept for the surface treatment of the SRF cavity prototype for the CLIC damping rings

Author: Daniel Bafia[1]

Co-authors: Alexej Grudiev [2]; Davida Smith [1]; Grigory Eremeev [1]; Hannah Hu [3]; Karol Scibor [2]; Robin Betemps [2]; Simon Barriere [2]; Thomas Demaziere [2]; Tim Ring [1]

[1] *Fermi National Accelerator Laboratory*

[2] *European Organization for Nuclear Research*

[3] *University of Chicago*

Corresponding Author: dbafia@fnal.gov

The Compact Linear Collider (CLIC) Damping Rings (DRs) must generate ultra-low emittance bunches to achieve high luminosity. This requires many wigglers with high energy loss, compensated by the RF system. The resulting strong beam loading transients pose a major challenge for RF system design. A novel 2 GHz SRF cavity with an ultra-low R/Q below 1 Ω is proposed to minimize these transients. Design and fabrication of a bulk Nb prototype, turned from a single piece and EB welded, are presented. A conceptual study of surface treatment to achieve the highest surface magnetic field —the goal of the prototype cold test—is also described. To enable excellent performance, we plan to apply a 75/120℃ modified low-temp bake with cold electropolishing. This approach consistently delivers high gradients and quality factors in TESLA-shaped 1.3 GHz SRF cavities. Adapting this for the 2 GHz ultra-low R/Q design aims to maximize surface magnetic field while minimizing residual resistance and field emission—critical to meeting CLIC DR RF performance requirements under high beam loading.

Monday Poster Session - Board: MOP25 / **103**

Horizontal testing of 648 MHz elliptical superconducting cavities for CSNS-II using dual-frequency signal method

Author: Xuerui Hao[1]

[1] *Institute of High Energy Physics*

Corresponding Author: xrhao@ihep.ac.cn

This study presents high-precision Q_0 measurements for 648 MHz elliptical superconducting cavities in horizontal testing at CSNS-II, using the dual-frequency method to address errors in fixed-coupling systems ($\beta \approx 360$) under high-field (6 MV/m) operation. Dynamic phase calibration and reflection suppression algorithms minimized cavity deformation and electromagnetic interference effects. Results showed Q_0 measurement errors below 4.2 %, a linear field response up to 6.3 MV/m, and 98.5 % parameter confidence, surpassing traditional decay-time methods. The -70 dB coupler-based phase compensation suppressed 75 % of parasitic noise, proving the method's robustness in complex electromagnetic environments. This work provides a standardized solution for high-β cavity batch validation in large accelerators and offers insights for high-current proton accelerator stability.

Monday Poster Session - Board: MOP26 / **326**

Impedance measurement setup design of a silicon carbide beamline higher-order-mode absorber

Author: Lin Guo[1]

Co-authors: Alex Zaltsman [1]; Jiquan Guo [2]; Michael Blaskiewicz [1]; Robert Rimmer [2]; Silvia Verdu-Andres [1]; Wencan Xu [1]; Zachary Conway [2]

[1] *Brookhaven National Laboratory*

[2] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: wxu@bnl.gov

Cylindrical shell silicon carbide (SiC) higher-order-mode (HOM) beamline absorbers (BLA) were developed and high-power tested for the 591 MHz single-cell superconducting radio frequency (SRF) cavities in the Electron Storage Ring of the Electron-Ion Collider. The material properties of the BLA are crucial for HOM damping and wakefield performance. However, discrepancies were observed between the material parameters measured from small SiC samples and those of the full SiC cylinder used in the BLA, which has a radius of 137 mm. To address this, a coaxial-type test setup was designed to measure the transmission characteristics and extract the material parameters of SiC. These parameters can be used for accurate HOM analysis in the 591 MHz SRF cavity string design.

Monday Poster Session - Board: MOP27 / **276**

Testing and delivery of high beta cavities for the European Spallation Source by UKRI-STFC Daresbury Laboratory

Author: Alan Wheelhouse[1]

Co-authors: Andrew Blackett-May [1]; Ayo Akintola [1]; Conor Jenkins [2]; David Mason [2]; Detlef Reschke [3]; George Miller [2]; Ivan Skachko [1]; Jennifer Mutch [2]; Lea Steder [3]; Mark Pendleton [2]; Mateusz Wiencek [3]; Michael Ellis [1]; Oliver Poynton [2]; Paul Smith [1]; Peter McIntosh [2]; Philip Hornickel [2]; Shrikant Pattalwar [1]; Stuart Wilde [4]; Zakia Bilques [2]

[1] *ASTeC, STFC Daresbury Laboratory*

[2] *Science and Technology Facilities Council*

[3] *Deutsches Elektronen-Synchrotron DESY*

[4] *Daresbury Laboratory*

Corresponding Author: alan.wheelhouse@stfc.ac.uk

The testing and delivery of 86 704 MHz high-beta superconducting RF (SRF) cavities as part of an In-Kind-Contribution (IKC) by Accelerator Science and Technology Centre (ASTeC) for the European Spallation Source (ESS) facility in Lund, Sweden has just been completed. The cavities have been manufactured by industry, Research Instruments in Germany, and have been tested at Daresbury Laboratory and Deutsches Elektronen-Synchrotron (DESY). The requirement for the cavities was to achieve an accelerating gradient of 18.9 MV/m at a Q0 of 5e10. A review of the test results is described.

Funding Agency:

UKRI-STFC

Monday Poster Session - Board: MOP28 / **306**

AUP progress: procurement and performance of crab cavities for the HL-LHC

Author: Alejandro Castilla[1]

Co-authors: Jean Delayen [2]; Leonardo Ristori [3]; Manuele Narduzzi [3]; Naeem Huque [1]; Subashini De Silva [2]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Old Dominion University*

[3] *Fermi National Accelerator Laboratory*

Corresponding Author: acastill@jlab.org

The High Luminosity Upgrade of the Large Hadron Collider (HL-LHC), set for completion by 2029, is a technology frontier initiative aimed at increasing the collider's luminosity by a factor of 10, enabling unprecedented precision in measurements and expanding the potential for groundbreaking discoveries in particle physics. A key component of this upgrade is the implementation of advanced superconducting technologies, including crab cavities, which rotate particle bunches to maximize collision overlap, and high-field Nb3Sn quadrupole magnets for improved beam focusing. The U.S. Department of Energy's (DOE) Accelerator Upgrade Project (AUP) is playing a critical role in this effort, particularly through the development and delivery of cutting-edge bulk niobium crab cavities. This paper will provide an overview of the procurement process with industry vendors, and detail the processing and performance efforts at FNAL and JLab. We will also share lessons learned and outline the roadmap toward final cavity delivery to TRIUMF for string assembly and cryostating, culminating in the installation of the fully tested cryomodules in the LHC tunnel by 2029.

Funding Agency:

DOE

Monday Poster Session - Board: MOP29 / **130**

Results from DQW cavity testing & validation for HL-LHC

Author: Katarzyna Turaj[1]

Co-authors: Amelia Edwards [1]; Nuria Valverde Alonso [1]

[1] *European Organization for Nuclear Research*

Corresponding Author: amelia.edwards@cern.ch

Four DQW series cavities used for vertical crabbing in HL-LHC have been manufactured and tested at the CERN vertical test facility. Each cavity undergoes a sequence of cold tests starting from the bare cavity up to the cavity in its final configuration with all HOM couplers and field antenna. Experience with the first batch of DQW series cavities on RF measurements during manufacturing and cold testing with a focus on RF measurements with HOM couplers is presented. Issues related with early quench on two of cavities with HOM couplers including field emission onset are discussed.

Monday Poster Session - Board: MOP30 / **131**

RFD crab cavity HOM evolution: cold tests, cryostating & cryomodule testing at 2 K

Author: Amelia Edwards[1]

Co-authors: Katarzyna Turaj [1]; Nuria Valverde Alonso [1]

[1] *European Organization for Nuclear Research*

Corresponding Author: amelia.edwards@cern.ch

As part of the High Luminosity LHC (HL-LHC) project, crab cavities will be installed around CMS and ATLAS experiments of the LHC. To accommodate the different crossing angle planes, two cavity designs have been selected: the RF Dipole (RFD) and the Double Quarter Wave resonator (DQW).

Two prototype RFD cavities were fabricated and successfully tested at CERN. Subsequently, the cavities were integrated into a dedicated cryomodule at STFC Daresbury in the UK. At CERN's SM18 test facility the cryomodule was tested at 2 K, validating RF, mechanical, and cryogenic performance. Very strong damping along with potentially high HOM power (~1 kW) is specified as a requirement for both crab cavity designs. This study presents the evolution of Higher Order Mode (HOM) measurements for the two RFD cavities, including measurement results from vertical tests and cryomodule tests at 2 K. The measured results are compared simulation data and used to qualify the prototype HOM couplers and their performance across test environments. Preliminary insights are also drawn from RFD cryomodule tests with beam at SPS.

Monday Poster Session - Board: MOP31 / **21**

Electromagnetic design of a quadrupole resonator for SRF materials at IMP

Author: Yong Zhao[1]

Co-authors: Shichun Huang [1]; Long Peng [2]; Yuan He [1]; MIngming Yu [3]; Xiangcheng Gu [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Lanzhou University*

[3] *Sichuan University*

Corresponding Author: zhaoyong@impcas.ac.cn

Comprehensive RF characterization of superconducting materials in a large range of multiparameters plays a pivotal role in research both on exploring material limits and understanding RF loss mechanism. This is particularly critical for emerging thin-film superconductors such as Nb_3Sn and superconducting-insulator-superconducting (SIS) heterostructures (e.g., NbTiN-AlN-Nb). The Quadrupole Resonator (QPR), originally developed at CERN, employing RF-DC compensation technique to measure surface resistance in a high resolution. A QPR operating at a fundamental frequency of 325MHz is under development at Institute of Modern Physics, CAS, the lower frequency means higher residual resistance sensitivity compared to existing systems at CERN and HZB. In this paper, the electromagnetic optimization following some crucial figure of merits will be showed, including avoiding (Δf = f_QPR –f_dipole >5 MHz), multipacting suppression (SEY > 1), and field emission control (B_pk/E_pk). Designs for P_in (input) and P_t (pick-up) couplers are detailed, alongside the cavity fabrication process.

Monday Poster Session - Board: MOP32 / **159**

RF testing and performance analysis of low beta superconducting cavities for HIAF and CiADS facilities

Author: Shihui Wei[1]

Co-authors: Feng Qiu [2]; Yuan He [2]; Zhijun Wang [2]

[1] *Institute of Modern Physics*

[2] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: hey@impcas.ac.cn

RF testing and performance analysis of low beta superconducting cavity cryomodules are in progress for the two facilities: High Intensity Heavy Ion Accelerator (HIAF) and Chinese initiative Accelerator Driven System (CiADS). This poster describes the status and progress of RF conditioning, plasma cleaning, key cavity parameter identification, cavity operation limits testing, and stability testing of cavities and cryomodules during horizontal and integration testing. Advanced measurement techniques are introduced, such as online measurement of key cavity parameters (loaded Q and cavity frequency) during cryomodule cooling-down process, as well as dynamic detuning and dynamic loaded Q identificatoin in SEL and GDR loops. In addition, cavity quench strong textbehaviors under pulsed and CW RF operations are also discussed.

Monday Poster Session - Board: MOP33 / **166**

Status of the 650 MHz elliptical cavities in IMP

Author: Yulu Huang[1]

Co-authors: TIANCAI JIANG [2]; Zhijun Wang [1]; Yuan He [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Institute of Modern Physics*

Corresponding Author: huangyulu@impcas.ac.cn

650 MHz multicell superconducting radio frequency (SRF) elliptical cavities are developed for stable acceleration of proton beam in the Chinese initiative Accelerator Driven Subcritical System (CiADS). Two families of such cavities with optimum beta equal to 0.62 and 0.82, respectively, were proposed to boost the beam energy from 175 MeV to 500 MeV, with the capabilities to upgrade the energy to higher level with additional Ellip.082 cryomodule. Electromagnetic design, mechanical Design and Multiphysics analysis of the cavities were performed, two prototype cavities were fabricated, post-processed and vertical tested. Overview status of the elliptical cavities will be discussed in the paper.

Monday Poster Session - Board: MOP34 / **263**

Vertical test results for ITN single cell cavities

Author: Eric Viklund[1]

Co-authors: Kensei Umemori [1]; Mathieu Omet [1]; Takafumi Hara [1]; ryo katayama [1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: eric.viklund@kek.jp

To support the ILC Technology Network (ITN) Cryomodule project at KEK, we have constructed and assembled six single cell cavities, four fine grain (FG) and two medium grain (MG) for vertical testing (VT). A series of surface treatment were applied to the cavities using the proposed recipe for the construction of the International Linear Collider (ILC). This recipe consists of four steps: bulk electropolishing (EP), annealing, cold EP, and finally two step baking. Using this recipe, we can consistently exceed the ILC specifications. We analyze the performance and characteristics of these cavities using Q vs E and temperature mapping measurements. One of the cavities was treated with a special recipe which skips the cold EP step to simplify the cavity preparation process. We find that this modified recipe is also able to exceed the ILC specification, however the quality factor was negatively affected.

Monday Poster Session - Board: MOP35 / **125**

Microstructural characterization of Nb3Sn thin films using 3D FIB tomography

Author: Eric Viklund[1]

Co-authors: David N. Seidman [2]; Sam Posen [3]

[1] *High Energy Accelerator Research Organization*

[2] *Northwestern University*

[3] *Fermi National Accelerator Laboratory*

Corresponding Author: eric.viklund@kek.jp

The accelerating gradient of Nb_3Sn superconducting radiofrequency (SRF) cavities is currently limited, and the underlying cause remains an open question in the field. One leading hypothesis attributes this limitation to the presence of tin-deficient regions within the Nb_3Sn coating, which can suppress the superheating field. Due to the relatively large coherence length of Nb_3Sn, defects near the surface may significantly interact with the RF field. However, these subsurface defects have proven difficult to characterize. In this contribution, we present an unprecedented level of detail into the structure and distribution of subsurface tin-deficient regions to better understand their influence on cavity performance. We employ 3D focused ion beam (FIB) tomography to analyze the subsurface microstructure of Nb_3Sn thin films. This technique enables three-dimensional reconstruction of both the tin distribution and the grain structure within the film. By correlating compositional variations with grain morphology, we gain insights into the formation mechanisms of tin-deficient regions and their potential role in limiting SRF cavity performance.

Monday Poster Session - Board: MOP36 / **172**

The fabrication of the 1.3 GHz single-cell cavities by niobium materials with fine and medium grain sizes

Author: HeeSu Park[1]

Co-authors: Junho Han [1]; Jongmo Hwang [2]; Eun-San Kim [2]; Takeshi Dohmae [3]; Takayuki Saeki [3]; Kensei Umemori [3]

[1] *Kiswire Advanced Technology Ltd.*

[2] *Korea University Sejong Campus*

[3] *High Energy Accelerator Research Organization*

Corresponding Author: cirrus23@kiswire.com

The collaboration research is conducted according to the ITN (ILC Technology Network). As a part of research into the manufacturing methods for SRF cavities used in ILC (International Linear Collider), two 1.3 GHz single-cell cavities were fabricated by utilizing fine and medium grain size niobium materials, respectively. Those cavities are manufactured by KAT Co., Ltd. in Korea under the research collaboration for ILC SRF cavity between KEK and KU (Korea University). Both cavities are fabricated with the same process and toolings including the pressing dies, machining jigs, and welding jigs. They have been tested in KEK and satisfied the required specification in the vertical test. This presentation shows lesson learn during the fabrication process of both cavities.

Monday Poster Session - Board: MOP37 / **169**

Strength evaluation of large grain niobium sheets and derivation of allowable stress

Author: Hiroaki Umezawa[1]

Co-authors: Masashi Yamanaka [2]; Naoshi Nishida [3]

[1] *The Graduate University for Advanced Studies, SOKENDAI*

[2] *High Energy Accelerator Research Organization*

[3] *Tokyo Denkai Co., Ltd.*

Corresponding Author: umezawa@tokyodenkai.co.jp

The high-purity niobium material used in the superconducting cavities is an ingot produced by electron beam melting, and is a polycrystalline with a grain size of 10 to 200 mm. Niobium sheets sliced from ingots contain large grains and called as large grain (LG). Superconducting cavities made from LG niobium have the advantages of a high maximum acceleration gradient, Q value, and low manufacturing cost. Large-numbered tensile testing at room temperature using two kinds of LG niobium sheets with RRR392 and RRR189 was performed. The tensile strengths are 79.2 MPa and 83.3 MPa, respectively, about half that of ordinary fine grain (FG) niobium. The variation of strength is significant due to crystal orientation. The minimum tensile strength was estimated based on material strength studies to apply the LG cavity to the High-Pressure Gas Safety Act, and the allowable stress for vessel design was derived. These are 12 MPa and 15 MPa, respectively, which are less than half that of FG niobium. The strength estimation method shown here can be applied with approximately 50 tensile testing results. It is also simple and versatile and does not require crystal orientation measurement.

Monday Poster Session - Board: MOP38 / **298**

SRF R&D activities at INFN-LASA

Author: Laura Monaco[1]

Co-authors: Angelo Bosotti [1]; Bastiano Vitali [1]; Carlo Pagani [2]; Daniele Sertore [1]; Elisa Del Core [3]; Fabrizio Fiorina [1]; Michele Bertucci [3]; Paolo Spruzzola [1]; Rocco Paparella [3]

[1] *Istituto Nazionale di Fisica Nucleare, Laboratori Acceleratori e Superconduttività Applicata*

[2] *Istituto Nazionale di Fisica Nucleare, Laboratorio Acceleratori e Superconduttività Applicata; University of Milan*

[3] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: laura.monaco@mi.infn.it

Sustainability and cost reduction are key factors for the development of future large particle accelerators. This has led INFN LASA to start an INFN-funded R&D program dedicated to studying and improving the performance of SRF Nb cavities in terms of quality factor (High-Q) and accelerating gradient (High-G). Moreover, the R&D program is also pushed by the INFN LASA contribution to international projects such as PIP-II and by the participation on the international collaboration ILC Technology Network (ITN). The strategy of the R&D program consists of studying and optimizing different surface treatments on 1.3 GHz single-cell cavities that will later be applied to 9-cell cavities in view of the industrialization process needed for large scale production. A key activity of this program is the upgrade of our experimental vertical cold test facility needed to enable the qualification of such high-performance cavities. Ongoing activities include a new dedicated cryostat designed to minimize the liquid helium inventory consumption, the implementation of an active magnetic field compensation for the reduction of trapped magnetic flux, and the usage of a wide range of diagnostics for quench, field emission, etc. This paper presents the current status of the facility and its key features, an overview of cavities currently in production, and the experimental results obtained to date.

Funding Agency:

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Monday Poster Session - Board: MOP39 / **218**

ITN in Europe: a coordinated effort for ILC technology development

Author: Laura Monaco[1]

Co-authors: Akira Yamamoto [2]; Enrico Cenni [3]; Hiroshi Sakai [2]; Karl-Martin Schirm [4]; Kensei Umemori [2]; Shinichiro Michizono [5]; Steinar Stapnes [4]; Takayuki Saeki [2]; Takeshi Dohmae [2]; Yasuchika Yamamoto [2]

[1] *Istituto Nazionale di Fisica Nucleare, Laboratori Acceleratori e Superconduttività Applicata*

[2] *High Energy Accelerator Research Organization*

[3] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

[4] *European Organization for Nuclear Research*

[5] *High Energy Accelerator Research Organization; The Graduate University for Advanced Studies, SOKENDAI*

Corresponding Author: laura.monaco@mi.infn.it

The ILC Technology Network (ITN) in Europe, in close collaboration with KEK and key institutions including CEA, CERN, INFN, is actively driving the development of advanced superconducting radiofrequency (SRF) technologies to support the realization of the International Linear Collider (ILC). The ITN-EU initiative focuses on developing and validating cost-effective, high-performance cavity production processes, transitioning from single-cell R&D to the industrialization of 9-cell cavities. Activities include optimizing surface treatment protocols, rigorous quality control of niobium materials, harmonization with Japanese High Pressure Gas Safety (HPGS) regulations, and preparing technical specifications for cavity jacketing and testing. As part of this program, Europe will contribute fully qualified SRF cavities to a globally designed ILC-type cryomodule for testing at KEK. The collaboration fosters knowledge exchange across laboratories and industry, supports advanced diagnostics development, and benefits from wider initiatives such as the Marie Skłodowska-Curie EAJADE network. These collective efforts not only support ILC realization but also reinforce Europe's strategic capabilities in SRF technology for future accelerators.

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Monday Poster Session - Board: MOP40 / **280**

Status of PIP-II HB650 cavities production

Author: Anna Shabalina[1]

Co-authors: Alan Wheelhouse [2]; Andrew Blackett-May [3]; Paul Smith [2]; Peter McIntosh [1]

[1] *Science and Technology Facilities Council*

[2] *Daresbury Laboratory*

[3] *ASTeC, STFC Daresbury Laboratory*

Corresponding Author: anna.shabalina@stfc.ac.uk

STFC is responsible for delivering 20 high-beta 650 MHz cavities for the PIP-II project, with industry partners now producing series cavities. Both pre-series cavities have set world records in performance and cleanliness, meeting the project's stringent requirement for field emission-free operation, accelerating gradient, and Quality factor. Achieving this milestone required an industrialization of advanced processing techniques, including cold electropolishing and nitrogen doping, and a major effort to optimize cleanroom operations at the vendor's facility.
We will present the journey from prototyping to industrial production, highlighting the technology transfer, cleanroom upgrades, and QA/QC procedures that enabled these record-breaking results. Early performance data from the first series cavities will also be shared, demonstrating progress toward full-scale production.

Monday Poster Session - Board: MOP41 / **15**

Enhancing bulk niobium quality: addressing surface pits and delamination in cavity manufacturing

Author: Anna Shabalina[1]

[1] *Science and Technology Facilities Council*

Corresponding Author: anna.shabalina@stfc.ac.uk

This talk presents an overview of the efforts to resolve niobium quality issues, specifically surface pits and delamination, encountered during cavity manufacturing for the PIP-II project. Initial surface quality problems led to a temporary suspension of production. Additionally, delamination was later discovered in both formed and unformed sheets, raising concerns about the material's integrity across multiple projects. This poster will detail the challenges faced, the investigative process, and the solutions implemented to restore and enhance the quality of niobium used in cavity manufacturing.

Monday Poster Session - Board: MOP42 / **288**

Experimental investigation of plasma processing for PIP-II SSR2 cavities

Author: Bianca Giaccone[1]

Co-authors: Donato Passarelli [1]; Mattia Parise [1]; Tommaso Aiazzi [1]; Vincent Roger [1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: giaccone@fnal.gov

Field emission and multipacting are critical factors that limit the achievable operational gradient of superconducting radio frequency (SRF) cavities. Plasma processing has been demonstrated as an effective in-situ technique for mitigating hydrocarbon-induced field emission and multipacting across a range of cavity geometries. In this work, we present the initial development and subsequent application of plasma processing for PIP-II type II spoke resonators (SSR2). The process was carried out at room temperature on an SSR2 cavity equipped with the CM-style high-power coupler and installed in the cryostat. Cavity performance was evaluated through comparative cold tests conducted before and after plasma processing.

Funding Agency:

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Monday Poster Session - Board: MOP43 / **227**

First results on plasma cleaning tests in a SSR1-type spoke resonator for PIP-II project at IJCLab

Author: David Longuevergne[1]

Co-authors: Bianca Giaccone [2]; Camille CHENEY [3]; David Le Dréan [3]; Donato Passarelli [2]; Guillaume Mavilla [3]; Lê My Vogt [3]; Mael Vannson [3]; Mattia Parise [2]; Nicolas Gandolfo [1]; Patricia Duchesne [3]; Patxi Duthil [3]; Tommaso Aiazzi [2]

[1] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

[2] *Fermi National Accelerator Laboratory*

[3] *Laboratoire de Physique des 2 Infinis Irène Joliot-Curie*

Corresponding Author: longuevergn@ipno.in2p3.fr

Plasma ignition studies have been initiated at IJCLab since 2022. These are focusing on “in situ” plasma decontamination of SRF cavities with complex geometries as Quarter Wave Resonator (QWR) and Single Spoke Resonators (SSR). IJCLab being strongly involved in PIP-II project and in particular in the qualification test of SSR1- and SSR2-type resonators, the vertical cryostat has been upgraded to implement plasma decontamination capabilities. With the support of Fermilab and Eurolabs project, the impact of plasma ignition on the performance of a prototype SSR1 cavity has been assessed. This paper will give an overview on the upgrade work done on the cryostat, on the plasma decontamination process and on the comparative analysis of the 2 vertical tests (before and after plasma process).

Funding Agency:

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Monday Poster Session - Board: MOP44 / **225**

CNRS contribution to PIP-II project: overview and lessons learned from SSR2 cavities prototyping phase

Author: David Longuevergne[1]

Co-authors: David Le Dréan [2]; Donato Passarelli [3]; Guillaume Mavilla [2]; Lê My Vogt [2]; Mael Vannson [2]; Matthieu Pierens [2]; Mattia Parise [3]; Nicolas Gandolfo [1]; Patricia Duchesne [2]; Patxi Duthil [2]; Sandry Wallon [2]; Sergey Kazakov [3]

[1] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

[2] *Laboratoire de Physique des 2 Infinis Irène Joliot-Curie*

[3] *Fermi National Accelerator Laboratory*

Corresponding Author: longuevergn@ipno.in2p3.fr

Since 2018, IJCLab is involved in PIP-II project on the design, development and qualification of accelerator components for the SSR2 (Single Spoke Resonator type 2) section of the superconducting linac. All pre-production components (cavity, coupler and tuner) have been fabricated and qualified either at IJCLab (tuner and cavity) and/or at FNAL (coupler and cavity). This paper will summarize all tests done during this prototyping phase at IJCLab.

Funding Agency:

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Monday Poster Session - Board: MOP45 / **232**

Preparation and qualification of pre-production SSR2 jacketed cavities for PIP-II

Author: Laura Grassellino[1]

Co-authors: Alexander Sukhanov [1]; Damon Bice [1]; David Longuevergne [2]; Donato Passarelli [1]; Kim Sang-Hoon [3]; Kyle Elliott [3]; Mattia Parise [1]; Ting Xu [3]; Tommaso Aiazzi [1]

[1] *Fermi National Accelerator Laboratory*

[2] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

[3] *Facility for Rare Isotope Beams*

Corresponding Author: laurag@fnal.gov

The qualification of 325 MHz Single Spoke Resonators type 2 (SSR2) jacketed cavities to meet technical requirements represents a significant milestone in the development of the SSR2 cryomodules for the PIP-II Project at Fermilab. This poster reports the procedures and lessons learned in processing and preparing these cavities for horizontal cold testing prior to integration into a cavity string assembly, with a focus on addressing the field emission issues observed during the cold testing. A comprehensive root cause analysis identified critical fabrication, processing, and handling factors

impacting field emission onset. New techniques were successfully developed and implemented to achieve field emission-free SSR2 cavities, and efforts were made to correlate radiation levels measured at the test stand with expected levels in the LINAC tunnel. Additionally, the evolution of field emission through assembly steps was thoroughly investigated, leading to a reassessment of design choices and enhancing our understanding of their effects on cavity performance.

Monday Poster Session - Board: MOP46 / **233**

Grinding studies for improvement of cavity sub-components manufacturing defects

Author: Laura Grassellino[1]

Co-author: Mattia Parise [1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: laurag@fnal.gov

The grinding process plays a crucial role in the fabrication of sub-components for 325 MHz spoke SRF cavities. During the forming and manufacturing stages, various defects can occur, which are addressed through grinding. This study aims to examine the effect of different grit sizes and explore how these sizes correlate with defect measurements. Optical microscopy and scanning electron microscopy (SEM) were employed to characterize the defects both before and after chemical treatment.

Monday Poster Session - Board: MOP48 / **266**

INFN LASA activities toward the PIP-II LB650 cavity production

Author: Rocco Paparella[1]

Co-authors: Angelo Bosotti [2]; Bastiano Vitali [2]; Carlo Pagani [2]; Daniele Sertore [2]; Donato Passarelli [3]; Elisa Del Core [1]; Fabrizio Fiorina [2]; Joseph Ozelis [3]; Laura Grassellino [3]; Laura Monaco [2]; Michele Bertucci [1]; Paolo Spruzzola [2]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *Istituto Nazionale di Fisica Nucleare, Laboratori Acceleratori e Superconduttività Applicata*

[3] *Fermi National Accelerator Laboratory*

Corresponding Author: daniele.sertore@mi.infn.it

This contribution outlines the current status and recent progresses of INFN LASA's in-kind contribution to the PIP-II project at Fermilab. It focuses on key manufacturing activities, on preliminary inspection results on sub-components and on upgrades to cavity testing infrastructures. The production of the 38, 5-cell, $\beta = 0.61$ SRF cavities designed by INFN LASA for the LB650 section of the linac is underway, starting with two pre-series units aimed at validating the full manufacturing and processing workflow. The series production is being carried out by industry, with cavities also undergoing most of surface treatments as well as final cleaning and preparation at vendor's premises. Final experimental qualification, to verify that cavities meet the challenging performance specifications required by the project, will be conducted through vertical cold tests at the DESY AMTF (Germany) facility before being delivered at CEA Saclay (France) as ready for string-assembly.

Monday Poster Session - Board: MOP49 / **217**

Update on INFN LASA in-kind contribution to ESS ERIC superconducting linac

Author: Daniele Sertore[1]

Co-authors: Angelo Bosotti [2]; Carlo Pagani [3]; Elisa Del Core [1]; Fabrizio Fiorina [2]; Laura Monaco [1]; Michele Bertucci [1]; Paolo Spruzzola [2]; Rocco Paparella [1]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *Istituto Nazionale di Fisica Nucleare, Laboratori Acceleratori e Superconduttività Applicata*

[3] *Istituto Nazionale di Fisica Nucleare, Laboratori Acceleratori e Superconduttività Applicata; University of Milan*

Corresponding Author: daniele.sertore@mi.infn.it

INFN-LASA has successfully completed its in-kind contribution to the European Spallation Source Eric, delivering 36 superconducting medium beta cavities for the ESS Linac. These cavities are designed to increase the energy of the proton beam from 216 MeV to 571 MeV. In addition, four spare cavities are being fabricated. This article outlines the performance of the cavities delivered so far and updates on the production status of the latest cavities.

Monday Poster Session - Board: MOP51 / **267**

HPR development for SSR cavities for RAON

Author: Juwan Kim[1]

Co-authors: Heetae Kim [1]; Yoochul Jung [1]; Youngkwon Kim [1]

[1] *Institute for Basic Science*

Corresponding Author: niceneph@ibs.re.kr

High-Pressure Rinsing (HPR) is one of the most important processes in achieving high performance of SRF cavities. The geometry of SSR cavities differs significantly from that of HWR and QWR cavities. For upgrading the HPR process for SSR cavities, it is important to understand how much of the inner surface area can be effectively reached by the waterjet from an HPR nozzle. HPR simulation software was developed to evaluate waterjet coverage based on parameters such as nozzle hole orientation, rotation speed, and translation speed of the nozzle rod. Prototype nozzles were fabricated for SSR1 and SSR2 cavities to improve rinsing performance. Testing of SSR1 and SSR2 cavities using these new nozzles is currently underway at IRIS. The nozzle design is being optimized based on simulation and experimental results.

Monday Poster Session - Board: MOP52 / **106**

Electromagnetic-thermal coupling study of the SHINE injector cavity

Author: Xinghao Guo[1]

Co-authors: Haixiao Deng [1]; Jinfang Chen [1]; ShenJie Zhao [2]; Xiaowei Wu [3]; Xuan Huang [2]

[1] *Shanghai Advanced Research Institute*

[2] *Shanghai Institute of Applied Physics*

[3] *Shanghai Zhangjiang Laboratory*

Corresponding Author: guoxh2023@shanghaitech.edu.cn

The SHINE project is a high-repetition-rate hard X-ray Free Electron Laser (XFEL) facility driven by a superconducting RF linear accelerator with an energy exceeding 8.0 GeV. The linear accelerator (LINAC) of SHINE consists of six hundred 1.3 GHz 9-cell cavities for acceleration, producing photons with energies ranging from 0.4 to 25 keV. This study focuses on the first single-cavity cryomodule of the LINAC which follows the electron gun. The injector cavity is a 1.3 GHz axisymmetric superconducting cavity with two fundamental power couplers. The accelerating gradient of the cavity reached 28 MV/m in the vertical test, but was limited below 8.1 MV/m in the horizontal test by thermal runaway. This did not meet the specification of 12 MV/m. Experiments revealed that the cause of thermal quench was insufficient cooling. Electromagnetic-thermal coupling simulation was performed to analyze this phenomenon and optimize the cooling conditions. The original cooling setup was enhanced and several new cooling configurations were proposed in the simulations. The optimization schemes showed a significant increase in the accelerating gradient. The injector cavity met the specification in horizontal test after applying the enhanced cooling scheme.

Monday Poster Session - Board: MOP53 / **63**

Detuning and strength optimization of an 1.3 GHz 7-cell SRF cavity for high current application

Author: Xinghao Guo[1]

Co-authors: Dong Wang [1]; Haixiao Deng [1]; Jinfang Chen [1]; Xiaowei Wu [2]; Xuan Huang [3]

[1] *Shanghai Advanced Research Institute*

[2] *Shanghai Zhangjiang Laboratory*

[3] *Shanghai Institute of Applied Physics*

Corresponding Author: guoxh2023@shanghaitech.edu.cn

To meet the growing demand for higher average power in Free Electron Laser (FEL), Energy Recovery Linac (ERL) technology, supported by superconducting radio frequency (SRF) cavities, offers significant performance and efficiency advantages. Shanghai Synchrotron Radiation Facility (SSRF) has initiated a project focused on the design of a 1 GeV ERL with an average beam current of 10 mA. This study presents the design and performance evaluation of an 1.3 GHz 7-cell main accelerating cavity, which is a core part of the system. Based on the completed RF design and optimization, structural analysis was carried out to assess the cavity's mechanical strength, helium pressure sensitivity, Lorentz force detuning, and modal behavior. As part of the mechanical design, simulation-based parameter sweeps were conducted on the stiffening ring radius to optimize its design, aiming to enhance the cavity's mechanical performance and frequency variation stability. These comprehensive optimizations enhance the overall capabilities of the cavity.

Monday Poster Session - Board: MOP54 / **270**

Cavities mass production for SHINE

Author: JIANBING ZHAO[1]

[1] *Institute of High Energy Physics*

Corresponding Author: zhaojb@ihep.ac.cn

The main accelerator of Shanghai High Repetition Rate X-ray FEL and Extreme Light Facility (SHINE) is an 8 GeV CW superconducting RF linac, which constructed by superconducting modules (8 X 9-cell 1.3 GHz TESLA type cavities). This article introduces the cavities progress that Beijing HE-Racing Technology Co., Ltd. (HERT) fabricated for SHINE.

Monday Poster Session - Board: MOP55 / **307**

HOM analysis of the 1.3 GHz 3-cell cavity for high-current beam acceleration

Author: Xuan Huang[1]

Co-author: Jinfang Chen [2]

[1] *Shanghai Institute of Applied Physics*

[2] *Shanghai Advanced Research Institute*

Corresponding Author: huangxuan@sinap.ac.cn

Recently, 1.3 GHz 3-cell superconducting cavities were proposed for the injector of the high-brightness free electron laser based on the energy recovery linac scheme. In the injector section, three cavities are required to accelerate a 10 mA electron beam to 10 MeV. The diameter of the beam pipe is increased to 100 mm to damp higher order modes (HOMs), which may lead to beam quality degradation or beam instability. This paper presents the HOM analysis, and HOM power is also calculated.

Monday Poster Session - Board: MOP56 / **309**

Centrifugal barrel polishing of the SHINE 1.3 GHz 9-cell cavities

Author: Xuan Huang[1]

Co-authors: Dong Wang [2]; Jiani Wu [2]; Jinfang Chen [2]; Shuai Xing [2]; Yue Zong [2]; Zheng Wang [1]; pengcheng dong [2]; yi huang [3]

[1] *Shanghai Institute of Applied Physics*

[2] *Shanghai Advanced Research Institute*

[3] *ShanghaiTech University*

Corresponding Author: huangxuan@sinap.ac.cn

The Shanghai high-repetition-rate XFEL and extreme light facility (SHINE) under construction is designed to be one of the most advanced free electron laser facilities in the world. The main part of the SHINE facility is an 8 GeV superconducting linac operating in continuous wave mode. The linac consists of seventy-five 1.3 GHz cryomodules. This paper presents the successful repair of defects in 1.3 GHz 9-cell cavities by centrifugal barrel polishing. Vertical test results show the improvement of cavity performance.

Monday Poster Session - Board: MOP57 / **154**

The design of a compact conduction-cooling system for SRF characterization

Author: GAI WANG[1]

Co-authors: Zhongxiang Xu [1]; Shengwen Quan [2]; Fang Wang [2]; Manqian Ren [2]; Zeqin Yao [2]; Xiang Zhang [2]; Ziyu Wang [2]

[1] *Anhui University*

[2] *Peking University*

Corresponding Author: 24052@ahu.edu.cn

The precise and efficient testing of the RF performance of superconducting radio frequency (SRF) samples under superconducting conditions serves as the fundamental support for developing new SRF materials. The traditional SRF material RF performance testing systems have technical bottlenecks such as strong dependence on liquid helium, long testing cycles, and high operating costs. In this paper, a conduction-cooling RF performance testing system for SRF materials is presented. This system has the ability to achieve high-field and high-resolution measurement of the surface resistance without liquid helium cooling. The system is designed based on an optimized mushroom-type sample host cavity, which mainly works at 3.9 GHz TE011 mode. The radius of the sample is 33 mm. The microwave surface loss of the cavity can be reduced by coating niobium-tin on the inner surface and the conduction-cooling structure is well designed. The resolution and range of Rs measurement are analyzed by Multiphysics simulation in this work.

Monday Poster Session - Board: MOP58 / **194**

Design of a 915 MHz conduction-cooled cryomodule

Author: Gianluigi Ciovati[1]

Co-authors: Alejandro Castilla [1]; Gary Cheng [1]; Gary Hays [1]; Jacob Lewis [2]; Jason Colley [1]; John Rathke [3]; John Vennekate [1]; Joshua Armstrong [1]; Keith Harding [1]; Thomas Schultheiss [4]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Old Dominion University*

[3] *TechSource (United States)*

[4] *TJS Technologies LLC*

Corresponding Author: hannesv@jlab.org

High-power, compact, continuous-wave (CW) linear electron accelerators with beam energies of up to 10 MeV are being considered for possible industrial applications. Conduction-cooled, superconducting radio-frequency (SRF) technology allows operating such machines at high electrical efficiency, thereby reducing the operating cost significantly. A prototype conduction-cooled SRF cryomodule has been designed and components are currently being manufactured. The cryomodule features a two-cell, 915 MHz SRF cavity, two cryocoolers, a fundamental power coupler, two magnetic shields, a thermal shield and warm-to-cold transitions. The cryomodule has been designed to be able to provide an energy gain of 3.5 MeV to a CW electron beam with a current of 5 mA. This contribution focusses on thermal and mechanical design aspects of the cryomodule.

Monday Poster Session - Board: MOP59 / **36**

Conduction-cooled operation of an SRF multi-cell cavity

Authors: John Vennekate[1]; John Rathke[2]; Tom Schultheiss[3]; Uttar Pudasaini[1]; Gary Cheng[1]; Drew Packard[4]; Keith Harding[1]

Co-author: Gianluigi Ciovati [1]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Advanced Energy Systems (United States)*

[3] *TJS Technologies*

[4] *General Atomics (United States)*

Corresponding Author: vennekate@jlab.org

The development of compact, SRF-based accelerators for applications beyond research is experiencing notable advancements due to the use of cryocoolers for conduction cooling instead of traditional liquid cryogens. Following the successful demonstration of a single-cell cavity operated through conduction cooling with three two-stage cryocoolers, Jefferson Lab has made strides in the operation of a multi-cell resonator. This milestone paves the way for high-energy applications of compact, conduction-cooled SRF machines. The demonstration, carried out in collaboration with General Atomics, took place in a dedicated horizontal test cryostat (HTC) at their San Diego facility. This presentation will highlight the technological developments, the latest results, and valuable lessons learned.

Monday Poster Session - Board: MOP60 / **162**

Initial conditioning of the 1.5 GHz prototype couplers for VSR demo

Author: Emmy Sharples-Milne[1]

Co-authors: Adolfo Velez [2]; Axel Neumann [1]; Jens Knobloch [3]; Nora Wunderer [1]; Pablo Echevarria [1]; Volker Dürr [1]

[1] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[2] *TU Dortmund University*

[3] *University of Siegen*

Corresponding Author: emmy.sharples@helmholtz-berlin.de

Two Prototype 1.5 GHz fundamental power couplers for the VSR (Variable pulse length Storage Ring) DEMO project at Helmholtz Zentrum Berlin (HZB), were produced by Research Instruments (RI) and Thales, with the aim to reach 16 KW CW. To allow for conditioning of the couplers in cold a dedicated coupler test stand was designed, installed and commissioned, creating a testing environment that mimics the module conditions. The couplers were initially delivered in March 2023 after substantial reworking, however due to leak tightness issues further reworking was required and were finally installed on the dedicated test stand in June 2024. Such significant levels of rework dictated the more cautious testing plan detailed in this paper. After a 120C baking, an initial short run of conditioning was performed August 2024, followed by a longer conditioning run in May of 2025. Here, we will present the first conditioning results for the VSR Demo prototype fundamental power couplers.

Monday Poster Session - Board: MOP61 / **22**

Design and testing of high power test bench for CiADS elliptical superconducting cavity input coupler

Author: Guochang liu[1]

Co-authors: Tiancai Jiang [1]; Yuan He [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: liuguochang@impcas.ac.cn

The Chinese initiative Accelerator Driven Subcritical System (CiADS) proposed by the Insitute of Modern Physics (IMP) will use 58 650 MHz input power couplers for low β and high β elliptical superconducting cavities, for continuous wave power up to 130 kW. Pre-design of 650 MHz couplers has been completed. In order to validate the performance of these couplers and effectively eliminate soft Multipacting through high power testing. A high power test bench was designed, machined and commissioned for 650 MHz elliptical superconducting cavity couplers. Due to the different coupling antenna lengths of the two types of superconducting cavity couplers, transmission performance of up to -35 dB was achieved by optimizing the structure of the test cavities of the high power test bench. The high power test bench utilizes forced air cooling to effectively reduce excessive temperature rise during high power testing. The high power test procedure for this coupler is also presented to be effective in reducing the conditioning time of the couplers.

Monday Poster Session - Board: MOP62 / **195**

Design and conditioning of a low thermal load coupler for conduction-cooled accelerators

Author: Haoyu Shen[1]

Co-authors: Zeqin Yao [1]; Xiaoxiao Wang [1]; Fang Wang [1]; Jiankui Hao [1]; Lin Lin [1]; Shengwen Quan [1]; Senlin Huang [1]

[1] *Peking University*

Corresponding Author: shenhy@stu.pku.edu.cn

Thermal management of high-power input couplers is a critical challenge in conduction-cooled superconducting accelerators. This work presents a low thermal load input coupler design featuring a detachable electromagnetic shield and a variable impedance stub to guide microwave-induced heat toward the 50 K region. RF and thermal simulations confirm its efficient power transmission and reduced heat load at cryogenic temperatures around 4 K. Experimental tests validate the electromagnetic shielding performance. High-power conditioning demonstrates stable 70 kW CW power transmission under ultra-high vacuum, meeting the dual requirements of low thermal load and high RF power handling for conduction-cooled accelerators.

Monday Poster Session - Board: MOP63 / **158**

Status of the power coupler for the half wave resonator in IRIS

Author: Junyoung Yoon[1]

Co-authors: Eiji Kako [2]; Daeboo Cha [3]; Dongkeun Lee [3]; Yeonsei Chung [1]; Yong Woo Jo [1]; Yong-Sub Cho [4]; Yoochul Jung [1]; Youngkwon Kim [1]; Sungmin Jeon [5]

[1] *Institute for Basic Science*

[2] *High Energy Accelerator Research Organization*

[3] *Vitzro Tech (South Korea)*

[4] *Korea Atomic Energy Research Institute*

[5] *Kyungpook National University*

Corresponding Author: jsminhi@ibs.re.kr

A heavy-ion accelerator facility was constructed for the Rare Isotope Science Project (RISP) at the Institute for Rare Isotope Science (IRIS) in Daejeon, Korea. The cryomodule with quarter-wave resonators (QWRs) and half-wave resonators (HWRs) was installed in the SCL (Superconducting Linac) 3 tunnel, and the beam commissioning (Beam energy = 16.4 MeV/u, 40Ar8+) has been completed. The geometry of the power coupler for the HWRs is a coaxial capacitive type based on a conventional 1-5/8 inch electronic industries alliance (EIA) 50 Ω coaxial transmission line with a single ceramic window. The multi-physics analysis, which includes electromagnetic, thermal, and mechanical analysis, was performed by ANSYS to evaluate the thermal expansion of the power couplers. In this paper, we present the analysis results and revised design of the power coupler for HWRs.

Monday Poster Session - Board: MOP64 / **310**

Fabrication of higher-order mode couplers for HL-LHC crab cavities at JLab

Author: Naeem Huque[1]

Co-authors: Adam O'Brien [1]; Gregory Grose [1]; Subashini De Silva [2]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Old Dominion University*

Corresponding Author: huque@jlab.org

The superconducting Radiofrequency Dipole (RFD) crab cavities for the Large Hadron Collider's High-Luminosity upgrade (HL-LHC) incorporate hook-style Horizontal Higher-Order Mode (HHOM) couplers to extract and damp HOMs, minimizing beam-cavity interactions. These couplers, fabricated from high-purity niobium, must maintain superconductivity under operational conditions at 2 K. As part of the U.S. contribution to the Accelerator Upgrade Project (AUP), Thomas Jefferson National Accelerator Facility (JLab) is responsible for the full fabrication and qualification of HHOM couplers for series-production cryomodules. The process includes vacuum brazing, electron-beam welding (EBW), precision metrology, and RF qualification. Couplers are first tested in a dedicated RF test box before integration with dressed RFD cavities, followed by qualification at 2 K in JLab's Vertical Test Area (VTA). Prototype HHOMs were fabricated and tested to validate design tolerances, assess performance on prototype cavities, and establish repeatable fabrication protocols. This paper presents key fabrication challenges, RF test results, and the current status of series production.

Monday Poster Session - Board: MOP65 / **308**

Development of a 197 MHz crab cavity cryomodule for the electron-ion collider

Author: Naeem Huque[1]

Co-authors: Chinmay Andhare [1]; Gary Cheng [1]; Justine Cox [1]; Subashini De Silva [2]; Zachary Conway [1]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Old Dominion University*

Corresponding Author: huque@jlab.org

Thomas Jefferson National Accelerator Facility (JLab) is leading the design and fabrication of all superconducting radiofrequency (SRF) cryomodules for the Electron-Ion Collider (EIC), to be built at Brookhaven National Laboratory (BNL). To achieve head-on luminosity at the interaction point, the EIC will employ SRF Radiofrequency Dipole (RFD) crab cavity cryomodules to compensate for the 25 mrad crossing angle. The hadron and electron storage rings (HSR and ESR) will utilize RFD cavities operating at 197 MHz and 394 MHz, respectively, with both frequencies used in the Hadron Storage Ring (HSR) and 394 MHz in the Electron Storage Ring (ESR). JLab is presently developing the 197 MHz cavity and associated cryomodule design. Each cavity is required to deliver a deflecting voltage of 11 MV, pushing the current limits of deflecting cavity performance and fabrication. This paper presents the key challenges in achieving these performance targets and highlights the innovative design solutions implemented for both the cavity and cryomodule systems.

Monday Poster Session - Board: MOP66 / **323**

Higher order modes couplers tuning optimization of 1.3 GHz 9 cell SRF cavities for SHINE project

Author: xiaoyun pu[1]

Co-authors: Hongtao Hou [2]; changhao cheng [1]; jing shi [1]

[1] *Shanghai Advanced Research Institute, Chinese Academy of Sciences*

[2] *Shanghai Advanced Research Institute*

Corresponding Author: puxy@sari.ac.cn

The Shanghai HIgh repetition rate XFEL aNd Extreme light facility (SHINE) project has entered its construction phase. This state-of-the-art facility includes an 8 GeV electron linear accelerator, which utilizes superconducting radio frequency (SRF) cavities. Each cryomodule within the accelerator comprises eight standard TESLA 1.3 GHz 9-cell superconducting cavities with two Higher Order Modes (HOM) couplers. Effective suppression of HOM is crucial to maintain beam quality and stability. This paper discusses the performance and adjustment experiences related to the HOM couplers integrated within SHINE's 1.3 GHz cryomodules. We present detailed results from vertical and horizontal tests, emphasizing the successful HOM notch filter tuning to maintain the fundamental mode HOM Qext above 3×10^{11} at 2K. Optimization strategies and revised specifications for HOM tuning have been established and formally approved.

Monday Poster Session - Board: MOP67 / **296**

Coupler installations on cavities at CEA followed by high power test in horizontal cryostat at Fermilab prior to the assembly of the PIP-II LB650 pre-production cryomodule

Author: Nicolas Bazin[1]

Co-author: Joseph Ozelis [2]

[1] *Commissariat à l'Energie Atomique*

[2] *Fermi National Accelerator Laboratory*

Corresponding Author: nicolas.bazin@cea.fr

The Proton Improvement Plan II (PIP-II) that will be installed at Fermilab is the first U.S. accelerator project that will have significant contributions from international partners. CEA joined the international collaboration in 2018 and will deliver 10 low-beta cryomodules as In-Kind Contributions to the PIP-II project, with cavities supplied by LASA-INFN (Italy) and VECC-DAE (India), and power couplers and tuning systems supplied by Fermilab. Before the start of the assembly of the LB650 preproduction cryomodule in the second half of 2025, the project decided to proceed with coupler installations on cavities at CEA followed by high power test in horizontal cryostat at Fermilab in order to validate the assembly process and infrastructure. This paper will present the results, including the one of a power coupler installed on a cavity using a robot.

Monday Poster Session - Board: MOP68 / **293**

RF conditioning of MYRRHA couplers at IJCLab

Author: Noureddine ElKamchi[1]

Co-authors: Christophe Joly [2]; Christopher Magueur [2]; Gilles Olivier [2]; Sylvain Berthelot [2]; Alice Thiebault [2]; Patricia Duchesne [2]; Olivier Frossard [2]; Véronique Poux [2]; Kaing Mon Mon Tun Lanoe [2]; Luc Perrot [2]

[1] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

[2] *Laboratoire de Physique des 2 Infinis Irène Joliot-Curie*

Corresponding Author: elkamchi@lal.in2p3.fr

Multi-purpose hYbrid Research Reactor for High-tech Applications (MYRRHA) is an experimental accelerator-driven system in development at SCK-CEN. It will allow fuel developments, material developments for GEN IV systems, material developments for fusion reactors and radioisotope production for medical and industrial applications. First phase of the project called MINERVA currently in construction at Mol in Belgium will deliver a 100 MeV-4 mA protons beams dedicated for applications and detailed studies of the reliability of the installation. IJCLab is engaged with the industrial monitoring, quality control, and RF conditioning of power couplers up to 60 kW at 352 MHz. The initial phase, which involved the conditioning of three pairs of prototype couplers, was completed in 2024. This phase enabled the identification of various areas for improvement in both the couplers, procedures and test bench [1]. In this paper, we will present and discuss the results of the conditioning of the couplers in full reflection mode. The conditioning results in full transmission mode have already been presented [1]. Additionally, we will outline the various enhancements made to the conditioning processes based on the findings from the prototype phase. These modifications are expected to improve the efficiency of the test bench and facilitate better conditioning of the series.

Footnotes:

[1] N. Elkamchi, C. Joly, C. Magueur, P. Duchesne, S. Berthelot, W. Kaabi, C. Lhomme « Proceedings of SRF2023 », Grand Rapids, USA

Monday Poster Session - Board: MOP69 / **268**

Design and CW RF transmission test up to 100 kW of L-band high-power input coupler

Author: Pragya Nama[1]

Co-authors: Ashish Kumar [2]; Dai Arakawa [2]; Eiji Kako [2]; Hiroshi Sakai [2]; Kensei Umemori [2]; Takako Miura [2]

[1] *The Graduate University for Advanced Studies, SOKENDAI*

[2] *High Energy Accelerator Research Organization*

Corresponding Author: pragya@post.kek.jp

A high-power input coupler was developed to transmit 100 kW-class RF power in continuous wave (CW) mode to a 1.3 GHz conduction-cooled superconducting accelerator. Both RF and thermal design optimizations were carried out to ensure efficient performance and compatibility with cryogenic constraints. Results of RF simulations showed a reflection coefficient of S1,1 = −44 dB at 1.3 GHz and a bandwidth of 24.6 MHz at the −20 dB level. Thermal simulations estimated the total static heat load to be approximately 1.2 W at the 4 K stage and 11.3 W at the 35 K stage, which is well within the cooling capacity of the available cryocoolers. To suppress the temperature increase under high RF power transmission, active water cooling was integrated into critical components, including the warm inner conductor, warm outer conductor antenna, and RF window. The newly developed coupler was successfully tested at a test stand under RF power up to CW 100 kW at room temperature conditions. A temperature rise at the inner conductor, which is the most critical component, was 15 ℃. A maximum temperature rise of 19 ℃ was recorded at the doorknob. The high-power test results demonstrated the coupler's capability to handle the target power level reliably while effectively mitigating thermal load during CW operation.

Monday Poster Session - Board: MOP70 / **167**

Status of the 650 MHz high power couplers in IMP

Author: TIANCAI JIANG[1]

Co-authors: Guochang liu [2]; Yuan He [2]; Zhijun Wang [2]

[1] *Institute of Modern Physics*

[2] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: jiangtiancai@impcas.ac.cn

The 650 MHz high power coupler has been designed and developed by IMP for medium-high beta elliptical superconducting cavities in the Chinese Initiative for Accelerator Driven Subcritical Systems (CiADS) project, delivering an average power of 130 kW. The coupler incorporates a door knob conversion structure, 75 ohm coaxial structure and dual warm window structure to achieve long term stable operation at high power. The electromagnetic design, multi-physical field analysis and mechanical design of the coupler have been completed, and prototype production of the coupler has been completed. The traveling and standing wave conditioning results of the coupler are discussed in this paper.

Monday Poster Session - Board: MOP72 / **33**

The horizontal testing of CSNS-II elliptical cryomodule

Author: Cong Zhang[1]

Co-authors: Ahong Li [1]; Bo Li [1]; Feisi He [1]; Huachang Liu [2]; Jin Dai [1]; MengXu Fan [3]; Pei Hua Qu [1]; Qi Yu Kong [2]; Qiang Chen [1]; Rui Ge [1]; Wenzhong Zhou [1]; Xiaolei Wu [2]

[1] *Institute of High Energy Physics*

[2] *Dongguan Neutron Science Center*

[3] *University of Science and Technology of China*

Corresponding Author: zhangcong@ihep.ac.cn

The China Spallation Neutron Source II (CSNS - II) necessitates 10 cryomodules equipped with double - spoke cavities and 8 cryomodules equipped with elliptical cavities to achieve the acceleration of H^- ions from 80 MeV to 300 MeV. Prior to their installation into the tunnel, each cryomodule must undergo horizontal testing and obtain certification. This paper will elaborate on the results of the horizontal tests.

Funding Agency:

Guangdong Basic and Applied Basic Research Foundation(Grant No.2022B1515120027)

Monday Poster Session - Board: MOP73 / **38**

The higher order mode study of CSNS-II superconducting Linac

Author: Cong Zhang[1]

Co-authors: Huachang Liu [2]; MengXu Fan [3]; Wenzhong Zhou [1]

[1] *Institute of High Energy Physics*

[2] *Dongguan Neutron Science Center*

[3] *University of Science and Technology of China*

Corresponding Author: zhangcong@ihep.ac.cn

The study of higher order modes (HOM) excited in the pulse mode superconducting Linac of CSNS-II is presented in this paper. The effects of cryogenic losses and influences on beam dynamics caused by the HOMs have been investigated.

Funding Agency:

Guangdong Basic and Applied Basic Research Foundation(Grant No.2022B1515120027)

Monday Poster Session - Board: MOP74 / **294**

Contactless RF shielded beamline warm-to-cold transition bellows for EIC ESR cryomodules

Author: Sergey Kuzikov[1]

Co-authors: Alexander Fuller [1]; Jiquan Guo [1]; Zachary Conway [1]

[1] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: jguo@jlab.org

In EIC ESR's cryomodules, beamline warm-to-cold transition bellows are required to provide mechanical compliance and thermal insulation for the cavity string. With up to 2.5 A beam current and 27.6 nC charge per bunch in the ESR, all these bellows need to be RF shielded due to concerns of both the tight HOM impedance budget and the strong HOM heating. Sliding contacts are not allowed due to cryomodule cleanliness concerns. In this paper, we will present the latest RF and thermal-mechanical design for these bellows.

Funding Agency:

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Monday Poster Session - Board: MOP75 / **221**

Cavity string design of the EIC ESR 591 MHz SRF cryomodule

Author: Jiquan Guo[1]

Co-authors: Alexander Fuller [1]; Alexei Blednykh [2]; David Savransky [1]; Eduard Drachuk [1]; Haipeng Wang [1]; Joseph Matalevich [1]; Nabin Raut [1]; Robert Rimmer [1]; Sergey Kuzikov [1]; Shaoheng Wang [1]; Wencan Xu [2]; Zachary Conway [1]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Brookhaven National Laboratory*

Corresponding Author: jguo@jlab.org

The Electron Ion Collider's (EIC) electron storage ring (ESR) requires a 591 MHz fundamental SRF system, providing up to 68 MV bunching voltage and replenishing up to 10 MW beam power loss from both synchrotron radiation and HOM. The high beam current of up to 2.5 A and a charge of up to 28 nC per bunch, combined with the large number of cavities and an operation energy as low as 5 GeV, impose very challenging HOM damping requirements. These include not only very high HOM power but also stringent limits on both the narrowband and the broadband impedance for all the cavity string components. In this paper, we will report the progress of the design of this cavity string.

Monday Poster Session - Board: MOP76 / **273**

Status of the cryomodule tests as a part of Polish in-kind contribution to the European Spallation Source (ESS) realized by IFJ PAN

Author: Jacek Swierblewski[1]

Co-author: Dariusz Bocian [1]

[1] *Institute of Nuclear Physics, Polish Academy of Sciences*

Corresponding Author: dariusz.bocian@ifj.edu.pl

The European Spallation Source (ESS), as one of the complex accelerators require installation and commissioning of many systems and components. One of them is the accelerator line which is composed with the cryomodules uses to accelerate of the particles. Taking into account that ESS is one of the most technological advanced accelerators in Europe we can expect also that accelerator line is very complex and advanced part of the machine. Among others things three types of the cryomodules spokes, medium and high beta are used to assembly accelerator line. In 2017 first group of engineers from the Henryk Niewodniczanski Institute of Nuclear Physics Polish Academy of Science (IFJ PAN) arrived to Lund in order to start execution of IFJ PAN contribution to this project. In total 31 cryomodules have to be tested and prepared for assembly in the tunnel as a part of the accelerator line. In this paper the current status of the tests as well as early stage of the optimization process regarding test program for cryomodules tests is showed. The main focus is done on the procedures and quality aspects, required skills and challenges occurring during the tests work; inter alia: incoming inspection, tests before installation in the bunker, preparation of the cryomodules for the test, test in the bunker, outgoing inspection. A very expensive RF cryomodules and systems required the special skills and the right approach to quality which is provided by engineers and technicians from IFJ PAN.

Monday Poster Session - Board: MOP77 / **109**

First ESS LINAC cooldown using the master automatic control sequence

Author: Emilio Asensi[1]

Co-authors: Adalberto Fontoura [1]; Horus Cardona [1]; Jianqin Zhang [1]; Marek Skiba [1]; Nishanthi Baskar [1]; Nuno Elias [1]; Pawel Halczynski [2]; Per Nilsson [1]; Philipp Arnold [1]; Wawrzyniec Gaj [2]

[1] *European Spallation Source*

[2] *Institute of Nuclear Physics, Polish Academy of Sciences*

Corresponding Author: emilio.asensi@ess.eu

This paper presents the key aspects of the cryogenic integrated control system for the ESS superconducting linear accelerator and its importance during the first operational experience in a LINAC configuration, enabling 2 MW beam power and beyond. This unified system is controlled by a master PLC managing the full CMDS (Cryomodules and Cryogenic distribution System) consisting of 43 cells, each comprising a Cryomodule with 352.21 MHz Double-Spoke or 704.42 MHz elliptical SRF cavities, and a valve box, which in turn are controlled by their own dedicated PLC. A key aspect of this integrated control system is the Master Automatic Control Sequence (MACS), which allows for the simultaneous cryogenic operation of the entire LINAC, managing and coordinating the different phases required for cryogenic operation, while handling failure response protocols and operator interface requirements. The paper also highlights lessons learned during the operation, identifies areas for improvement, and proposes strategies for optimizing SRF cryogenic controls in the upcoming phases of the ESS project.

Monday Poster Session - Board: MOP78 / **148**

Gamma-based diagnostics of field emission in SRF cavities and cryomodules using plastic scintillators: a joint study at ESS TS2

Author: Enrico Cenni[1]

Co-authors: Cecilia Maiano [2]; Guillaume Devanz [3]; Olivier Piquet [1]

[1] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*
[2] *European Spallation Source*
[3] *Commissariat à l'Energie Atomique*

Corresponding Author: enrico.cenni@cea.fr

Field emission is a major parasitic phenomenon that limits the performance of superconducting RF (SRF) cavities. It leads to the generation of dark currents and bremsstrahlung gamma rays, which in turn cause increased cryogenic load, local heating, and in severe cases, cavity quench. Moreover, the high dose rates produced in the proximity of the cavity can result in material damage and activation, posing additional challenges for maintenance and safe operation. The maturity of plastic scintillator technology, combined with recent advances in fast digital acquisition systems, enables the development of compact and sensitive diagnostics for these emissions. We present a modular gamma detection system based on plastic scintillators with various geometries, designed for temporally and spatially resolved measurements. Different prototypes have been deployed at the TS2 facility of the European Spallation Source (ESS) to monitor gamma radiation during RF tests. Preliminary results confirm its ability to detect field emission onset and localize emission regions, offering a promising tool for understanding emission mechanisms and improving SRF cavity performance and reliability.

Monday Poster Session - Board: MOP79 / **292**

Insights into the cryogenic operation of the ESS superconducting cryomodules during the first commissioning phase

Author: Marek Skiba[1]

Co-authors: Agnieszka Zwozniak [1]; Artur Krawczyk [2]; Cecilia Maiano [1]; Henry Przybilski [1]; Nuno Elias [1]; Paolo Pierini [1]; Peter Van Velze [1]; Philippe Goudket [1]

[1] *European Spallation Source*
[2] *Institute of Nuclear Physics, Polish Academy of Sciences*

Corresponding Author: marek.skiba@ess.eu

The first commissioning run of the superconducting cryomodules at the European Spallation Source (ESS) provided important insights into the performance of the cryogenic systems. This paper reviews the cryogenic operations, with a focus on cooldown processes, pressure control, temperature stability, and overall system reliability. The effectiveness of individual helium bath pressure regulation in managing pressure transients during cavity quenches and RF trips is demonstrated. The response of the system to cryoplant trip events is also analyzed. In addition, results from automated heat load measurements are presented, confirming that the thermal performance meets expectations. These findings demonstrate the robustness of the ESS cryogenic systems.

Monday Poster Session - Board: MOP80 / **50**

Enhancing niobium films for SRF and quantum applications

Author: Bektur Abdisatarov[1]

Co-authors: Grigory Eremeev [1]; Elsayed Ali Hani [2]; Daniel Bafia [1]; Akshay Murthy [1]; Alexander Romanenko [1]; Anna Grassellino [1]; Carlota Carlos [3]; Guillaume Rosaz [3]; Sergio Calatroni [3]

[1] *Fermi National Accelerator Laboratory*
[2] *Old Dominion University*
[3] *European Organization for Nuclear Research*

Corresponding Author: bektur@fnal.gov

Niobium films are crucial for superconducting radiofrequency cavities and two-dimensional superconducting transmon qubits. However, performance issues such as the medium-field Q-slope in Nb film cavities and microwave dissipation in qubits persist. To identify the limiting factors in Nb film performance, we used DC biased high-power impulse magnetron sputtering to deposit niobium films onto a 1.3 GHz single-cell elliptical bulk niobium cavity. By systematically modifying the material properties and microstructure through annealing, we identified the key limiting parameters. Annealing at 340℃ raised the quench field from 10.0 to 12.5 MV/m, while treatments at 600 ℃ and 800 ℃ for 3 hours increased it to 15.3 MV/m. Extending to 6 hours at 800 ℃ further improved the quench field to 17.5 MV/m. Reduced field-dependent losses were linked to the mitigation of hydrides, local misorientation, and defects. Using the same cavity to isolate Nb film losses from other materials in the qubit allowed us to pinpoint losses due to the Nb film and the metal-air interface. Operating the cavity in the quantum regime, we correlated RF losses to material parameters. The microwave dissipation mimicked the high intrinsic Q0 of bulk Nb cavities, with lifetimes extending into seconds. Nb film microstructure and impurity levels had minimal impact, with the oxide layer being the primary limitation in qubit performance. These findings advance efficient SRF technologies and extend qubit coherence times.

Monday Poster Session - Board: MOP81 / **254**

High-Q 3D niobium λ/4 coaxial cavities for quantum applications inspired by SRF technologies

Author: Takaaki Takenaka[1]

Co-authors: Imran Mahboob [1]; Shiro Saito [1]; Takayuki Kubo [2]; Takayuki Saeki [2]

[1] *NTT Basic Research Laboratories*
[2] *High Energy Accelerator Research Organization*

Corresponding Author: takaaki.takenaka@ntt.com

High-Q three-dimensional (3D) superconducting cavities are often used for quantum application including dielectric constant measurement, quantum memory[1], and dark matter detection[2]. In these experiments, a high-Q cavity is integrated with a superconducting qubit, which yields circuit-based Quantum Electrodynamics (cQED) architecture. The cavity geometry employed for quantum applications is radically different from that used for particle accelerators like a TESLA cavity. Most recently 3D cQED platforms are composed of a λ/4 coaxial cavity[1] which permits strong enough coupling between the superconducting qubit and the coaxial cavity to manipulate the quantum state of the cavity whilst sustaining internal Q factors of 1e9[3]. However, the best internal Q factor for these types of cavities is still an order of magnitude smaller than TESLA cavities. The origin of the reduced internal Q factor for λ/4 coaxial cavities has still not been clarified. One prominent candidate for the source of loss stems from the fact that 3D cQED devices for quantum applications are operated in the low-power limit, which is insufficient to saturate oxide defects on the cavity surface. In this study, various surface treatments are investigated with the aim to improve the lifetimes of 5.5 GHz λ/4 coaxial cavities. The internal Q factor after each treatment will be reported in this study and the most effective methods to fabricate a high-Q cavity for quantum applications will be discussed.

Footnotes:

[1] M. Reagor, et al., PRB 94, 014506 (2016).
[2] K. Nakazono, et al., arXiv:2505.15619 (2025).
[3] A. Oriani, et al., arXiv:2403.00286 (2024).

Funding Agency:

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Monday Poster Session - Board: MOP82 / **317**

591 MHz single-cell cavity optimization using evolutionary algorithms

Author: Guangjiang Li[1]

Co-authors: Wencan Xu [1]; Silvia Verdu-Andres [1]; Binping Xiao [1]; Alexander Zaltsman [1]

[1] *Brookhaven National Laboratory*

Corresponding Author: gli3@bnl.gov

A 591 MHz superconducting RF cavity is designed for the Electron Storage Ring (ESR) of the Electron-Ion Collider (EIC), providing an accelerating voltage of up to 4 MV. Based on the requirements for Robinson stability and suppression of multipacting effects, four key physical parameters are specified: the fundamental mode frequency should be 591 MHz ± 0.1 MHz; the R/Q of the fundamental mode (591 MHz) must be less than 80 Ω; the peak electric field should be less than 40 MV/m; and the peak magnetic field should be less than 80 mT. To meet these goals with minimal computation time, we propose using the multi-objective optimization algorithm NSGA-III (Non-dominated Sorting Genetic Algorithm III) for cavity geometry design. We combined the Poisson Superfish electromagnetic simulation with the genetic algorithm in a Python environment. A Pareto-optimal front was obtained after about 50,000 iterations. The peak electric field was successfully reduced by 20% without deteriorating the other three objectives. In the future, these datasets can be analyzed using machine learning algorithms to identify patterns relevant to various axisymmetric cavities for different beam manipulation applications.

Monday Poster Session - Board: MOP83 / **318**

Trapped mode and wakefield evaluation of bellows for 197 MHz superconducting crab cavities

Author: Guangjiang Li[1]

Co-authors: Binping Xiao [1]; Naeem Huque [2]; Justine Cox [2]; Wencan Xu [1]; Silvia Verdu-Andres [1]; Alexander Zaltsman [1]

[1] *Brookhaven National Laboratory*

[2] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: gli3@bnl.gov

Stainless steel bellows are used to connect the 197 MHz superconducting crab cavities, to compensate for the cavity displacement due to cryogenic temperature changes. The impedance of the bellows should be evaluated for both wakefield effects and the potential high order trapped modes. In the nominal bellows one longitudinal trapped mode was found at 2252 MHz, located between two nearby harmonic frequency lines in the beam spectrum for the 0.7 A average current with 290 proton bunches. Mechanical simulations were performed to evaluate the compressed, extended, and transversely deformed states of the bellows. The trapped modes in all configurations remained well confined within the two harmonic frequencies. The ohmic losses of the trapped modes are calculated accounting for the mechanical and electrical conductivity at both 4 K and room temperature. The

differences were found to be negligible, indicating that the bellows can also be used in the cold-to-warm transition between the crab cavity and the beam pipe. A preliminary short-range wakefield was calculated as a basis for subsequent long-range wakefield analysis.

Hot Topic Session: 1 - Board: HT1 / **315**

Hot Topic 1: sustainability of accelerator facilities

Author: Robert Laxdal[1]

Co-authors: Arnaud Madur [2]; Jie Gao [3]; Sergey Belomestnykh [4]

[1] *TRIUMF*

[2] *CEA Paris-Saclay*

[3] *Chinese Academy of Sciences*

[4] *Fermi National Accelerator Laboratory*

Corresponding Authors: arnaud.madur@cea.fr, gaoj@ihep.ac.cn, lax@triumf.ca, sbelomes@fnal.gov

There is increasing awareness within the global community of the need for meaningful actions on energy consumption and sustainability. High energy physics installations consume large quantities of energy and non-recoverable resources. Existing operation is being challenged to reduce consumption and new projects are being scrutinized for a full life cycle impact. Future developments of accelerator science and technology will be required with increasing urgency to improve efficiency of operation, promote more sustainable accelerator concepts and reduce environmental impact of our facilities. While noting that SRF is an intrinsically efficient technology there are steps that our community can contribute to support the cause. The hot topic session will host panelists from each of the three global regions to discuss on-going efforts to enable big science to proceed in a more sustainable way and the role that superconducting rf can play in that initiative.

Tuesday Oral Session: A - Board: TUA01 / **37**

Recent progress of SRF linac projects, HIAF and CiADS, at IMP

Author: Yuan He[1]

Co-authors: Shichun Huang [2]; TIANCAI JIANG [2]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Institute of Modern Physics*

Corresponding Author: hey@impcas.ac.cn

IMP is currently constructing three major SRF linacs: the High Intensity Heavy Ion Accelerator (HIAF), the China Initiative Accelerator Driven System (CiADS), and the Isotope Platform based on a high current superconducting linac (IP-SAFE), and operating one superconducting linac for Super Heavy Elements (CAFE2). This talk will report recent progress of these projects with emphasis on SRF equipment, operation stability, and discuss lessons learned. R&D activities to meet high demands on mass production and testing will also be presented, which includes robot-assisted clean assembly, RF testing, cryomodule design and testing, performance analysis, as well as new methods and innovative structures.

Tuesday Oral Session: A - Board: TUA02 / **9**

The path to high duty cycle (HDC) at EUXFEL: cryomodule developments

Author: Serena Barbanotti[1]

Co-authors: Detlef Reschke [1]; Julien Branlard [1]; Lea Steder [1]; Nicholas Walker [1]

[1] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Author: serena.barbanotti@desy.de

The European XFEL is in operation since 2017 with a maximum energy of 17.5 GeV in short-pulse (SP) mode, consisting of 0.65 ms-long bunch trains at 10 Hz repetition rate. The accelerator can deliver up to 2700 electron bunches every 100 ms, with a spacing between bunches of 220 ns. After eight years of successful operation the accelerator team, with strong support from the XFEL strategy process, is working to define an accelerator upgrade scenario for possible implementation in the next decade. The main goal of the upgrade is to facilitate more bunches per second with larger bunch spacing while maintaining the high energy of the beam, a world record amongst FEL machines. Possible scenarios include continuous-wave (CW) and long-pulse operating modes, collectively referred to as high duty cycle (HDC). This paper describes the different operating modes under investigation and the R&D activities ongoing at DESY to support the upgrade. The main focus of the paper is on the cryomodule and cavity design modifications, while also giving a brief introduction of the other challenging aspects connected to the upgrade.

Tuesday Oral Session: A - Board: TUA03 / **101**

Progress of CSNS-II SRF system

Author: Rui Ge[1]

Co-authors: Cong Zhang [1]; Feisi He [1]; Wenzhong Zhou [1]

[1] *Institute of High Energy Physics*

Corresponding Author: gerui@ihep.ac.cn

The China Spallation Neutron Source (CSNS) is the fourth pulsed accelerator-driven neutron source in the world. Meanwhile, it is one of the core large-scale scientific facilities of the Guangdong-Hong Kong-Macao Greater Bay Area Comprehensive National Science Center. The planned China Spallation Neutron Source Phase II (CSNS-II) started construction in 2024 and is scheduled to be completed in July 2029. To achieve a beam power of 500 kW for target station, the beam energy of the linear accelerator needs to be increased to 300 MeV. Therefore, a superconducting linear accelerator composed of two types of superconducting cavities, namely 324 MHz double-spoke cavities with β0 is 0.5 and 648 MHz 6-cell elliptical cavities with βg is 0.62, will be added after the Drift Tube Linac (DTL). We have completed the R&D of a prototype double-spoke cavity cryomodule and two prototype elliptical cavities. The test results showed that the maximum gradients of the two double spoke cavities at a pulse width of 4 ms and a repetition frequency of 25 Hz was 15.2 MV/m during horizontal test, while the maximum gradient of the elliptical cavity reaches 25.7 MV/m during vertical test. Both type cavities test results indicate that the design and post processing are very reliable, the mass production of superconducting cavities, couplers, tuners, and cryostats has been initiated, with plans to complete the manufacturing of all cryomodules by early 2027.

Tuesday Oral Session: A - Board: TUA04 / **26**

Studies of in-situ baking of SRF niobium cavities without a furnace at HZB

Author: Alena Prudnikava[1]

Co-authors: Alexander Matveenko [1]; Axel Neumann [1]; Jens Knobloch [2]; Oliver Kugeler [1]; Yegor Tamashevich [1]

[1] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[2] *University of Siegen*

Corresponding Author: alena.prudnikava@helmholtz-berlin.de

A specialized setup was designed to carry on a mid-T baking of SRF niobium cavities. It utilizes resistive heaters installed on the outer cavity walls, with a cryostat serving as a vacuum vessel. Based on our material studies with the real-time in-situ synchrotron XPS, a single-cell 1.3 GHz cavity was thermally treated in the regime providing contamination-free oxygen doping of niobium. RF tests of the cavity showed a significant reduction in surface resistance, primarily due to a decrease in residual resistance, with no field emission or degradation of the maximum accelerating field. This developed procedure can be potentially applied to bake "dressed"cavities prior to cryomodule assembly without breaking the cavity vacuum, thereby preventing surface re-oxidation and allowing the full benefits of mid-T baking to be realized in a real accelerator environment.

Tuesday Oral Session: A - Board: TUA05 / **102**

Enhancement of medium-temperature heat-treated SRF cavities for high quality and high gradient with supporting sample investigations

Author: Julia Goedecke[1]

Co-authors: Jennifer Ademoye [2]; Christopher Bate [1]; Karol Kasprzak [1]; Detlef Reschke [1]; Lennart Trelle [1]; Hans Weise [1]; Mateusz Wiencek [1]; Lea Steder [1]

[1] *Deutsches Elektronen-Synchrotron DESY*

[2] *Universität Hamburg*

Corresponding Author: julia.goedecke@desy.de

The heat treatment of SRF cavities at medium temperature (250 ℃ to 350 ℃), also known as "mid-T heat treatment", is one of the R&D activities at DESY towards a high-duty-cycle (HDC) upgrade of the European XFEL. Such treated cavities exhibit an improvement in the quality factor Q0 (3E10 to 5E10) at a moderate accelerating electric field strength Eacc (10 MV/m to 20 MV/m) compared to EuXFEL cavities. In fact, cavities treated in this way do experience quenching at Eacc in the range of 20–30 MV/m, i.e. they cannot be operated at gradients above 30 MV/m. However, in this work, we have found that a heat treatment consisting of a combination of mid-T and low-T not only favorable high Q0-values were measured, but additionally high gradients of up to 40 MV/m could be achieved. This offers great potential for upgrading modern LINACs with new high usable performance. The results of 1.3 GHz TESLA-type single- and nine-cell cavities as well as the influence of the effective oxygen diffusion length l will be presented. Further insights into the surface of Nb are provided by supporting sample analyses.

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Tuesday Oral Session: A - Board: TUA06 / **72**

SIS multilayer studies and status of the new cavity-coating system at University of Hamburg

Author: Lea Preece[1]

Co-authors: Alick Macpherson [2]; Daniel Turner [2]; Getnet Kacha Deyu [1]; Isabel González Díaz-Palacio [1]; Maciej Oskar Liedke [3]; Marc Wenskat [1]; Sebastian Klug [3]; Wolfgang Hillert [1]

[1] *Universität Hamburg*

[2] *European Organization for Nuclear Research*

[3] *Helmholtz-Zentrum Dresden-Rossendorf*

Corresponding Author: lea.preece@desy.de

Theories predict that Superconducting-Insulating-Superconducting (SIS) multilayers delay vortex penetration allowing for operation gradients more than twice of bulk Nb cavities and significantly higher Q-values [1]. The University of Hamburg focuses on Atomic Layer Deposition (ALD) as the most promising technique to coat SIS multilayers. A proof-of-principle experiment to coat cavities with an insulator has been successfully carried out, and the complex coating process was numerically modelled, which resulted in a further process time reduction while maintaining the high film quality [2,3]. For SIS multilayer deposition, plasma-enhanced ALD (PEALD) is used to deposit AlN and NbTiN as dielectric and superconducting material, respectively. The deposition process and post-deposition treatments have been optimized by studying the superconducting properties of the NbTiN thin film [4]. Moreover, properties such as flux-trapping behaviour and thermal transmittance of SIS multilayers have been measured. Furthermore, various material characterization techniques were applied to investigate the contribution of vacancy densities, recrystallization eVects due to the annealing past the deposition and the impact of the insulating layer on the properties of SIS multilayers. This talk will show the aggregated results of all those measurements and present the status of the PEALD single-cell cavity coating device at the University of Hamburg.

Footnotes:

[1] A. Gurevich, Applied Physics Letters 88, 12511 (2006).
[2] Wenskat. M, Deyu. G. et al., Superconductor Science and Technology 36.1 (2022): 015010.E.
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Tuesday Oral Session: B - Board: TUB01 / **98**

Systematic study of annealing effects on RF properties of HiPIMS Nb film

Author: Bektur Abdisatarov[1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: bektur@fnal.gov

This talk will make a report on investigating performance of Nb thin films and in particular: effect of sequential heat treatments on mid field Q-slope and quench of Nb thin films effect of film vs bulk vs the Nb oxide in losses of the films in the quantum regime. This innovative study investigates a thin film of HiPIMS niobium deposited on a bulk niobium cavity. Measurements at FNAL investigated the performance of the film as compared to the bulk cavity it was coated on, and after subjecting the

cavity to multiple and sequential heat treatment ranging from low temperature to mid temperature, to high temperature. Interestingly heat treatments in the range of 800 C demonstrate a significant improvement in mid-field Q slope and quench field. Studies have been performed with T-map to study the evolving character of the film losses for both slope and quench. Investigation into performance in the quantum regime demonstrate unequivocally that the leading role of low field Q-slope and TLS losses stems from the surface oxide and not from the Nb film or niobium bulk.

Tuesday Oral Session: B - Board: TUB02 / **55**

Nb3Sn coating and conduction cooling R&D at KEK

Author: Tomohiro Yamada[1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: ytomohi@post.kek.jp

KEK has performed R&D toward Nb3Sn accelerator. Investigation is carried out to optimize coating parameters, such as amount of Sn, process of nucleation, coating and annealing, toward realize higher performance of cavity. Simultaneously study on conduction cooling by cryo-cooler and design of Nb3Sn cryomodule are ongoing. Currently horizontal cryostat for Nb3Sn cavity is under construction and test is planned on 2025 spring.

Tuesday Oral Session: B - Board: TUB03 / **47**

Advancements in HF-free bipolar pulsed electropolishing for next-generation superconducting cavities

Authors: Hui Tian[1]; Rong-Li Geng[1]

Co-author: Mingqi Ge [1]

[1] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: geng@jlab.org

Hydrofluoric acid (HF)-free bipolar pulsed electropolishing (BPEP) offers an environmentally sustainable alternative to conventional Buffered Chemical Polishing (BCP) and Electropolishing (EP) techniques for superconducting radiofrequency (SRF) cavities. Recent studies at Jefferson Lab have demonstrated that a single-cell 1.3 GHz niobium cavity processed using HF-free BPEP achieved an accelerating gradient Eacc of 35 MV/m with a quality factor Q0 of 1E10 at 2 K, following extensive research and optimization. This talk will highlight the challenges encountered in developing this technique, key insights gained from experimental studies, and ongoing efforts to enhance its capabilities. In particular, we will explore its potential for refining Nb3Sn-coated niobium cavities via vapor diffusion techniques and for electroplating Nb3Sn films onto various cavity substrates, contributing to the advancement of high-performance SRF systems.

Tuesday Oral Session: B - Board: TUB04 / **10**

Plasma electrolytic polishing of 1.3 GHz cavities

Author: Eduard Chyhyrynets[1]

Co-authors: Carlota Carlos [2]; Cristian Pira [1]; Davide Ford [1]; Dorothea Fonnesu [1]; Fabrizio Stivanello [1]; Giorgio Keppel [1]; Guillaume Rosaz [2]; Hayato Araki [3]; Masashi Yamanaka [3]; Matteo Lazzari [4]; Oscar Azzolini [1]; Tochukwu Emmanuel Ezeaba [5]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *European Organization for Nuclear Research*

[3] *High Energy Accelerator Research Organization*

[4] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro*

[5] *University of Padua*

Corresponding Author: eduard.chyhyrynets@lnl.infn.it

The performance of superconducting radio frequency (SRF) cavities is critically influenced by surface preparation. Traditionally, electropolishing (EP) has been employed to achieve a clean, low-roughness surface on both niobium (Nb) and copper (Cu) substrates, despite requiring harsh and corrosive acids. Since 2019, our research at LNL has focused on an alternative approach: Plasma Electrolytic Polishing (PEP). This method uses only diluted salt solutions, presenting several advantages over EP, including a superior removal rate (2-8 µm/min for Nb and 3-30 µm/min for Cu) and achieving a surface roughness (Ra) lower than tens of nm. Additionally, the set-up has been optimized and simplified using external cathodes (no cathodes placed inside the elliptical cavity are necessary). In 2022, we established the initial recipes for PEP, and four of them were subsequently patented in 2023. First successful applications included a Cu 6 GHz elliptical cavities, QPRs and 3D-printed devices. In august 2024 the process scaling to 1.3 GHz Cu elliptical cavity has been done successfully. A collaboration with CERN and KEK is ongoing to validate the RF performances of PEP on a hydroformed seamless cavity produced by KEK and coated with a Nb thin film at CERN. On this talk PEP scaling to 1.3 GHz geometry and first RF results will be reported.

Funding Agency:

Work supported by the PNRR MUR project PE0000023-NQSTI

Tuesday Oral Session: B - Board: TUB05 / **16**

Plasma processing of FRIB low-beta cryomodules using higher-order modes

Author: Patrick Tutt[1]

Co-authors: Kenji Saito [1]; Kyle Elliott [1]; Sang-Hoon Kim [1]; Ting Xu [1]; Walter Hartung [1]; Wei Chang [1]

[1] *Facility for Rare Isotope Beams*

Corresponding Author: tutt@frib.msu.edu

Improvement in SRF accelerator performance after in-tunnel plasma processing has been seen at SNS and CEBAF. Plasma processing development for FRIB quarter-wave and half-wave resonators (QWRs, HWRs) was initiated in 2020. Plasma processing on individual QWRs (beta = 0.085) and HWRs (beta = 0.53) has been found to significantly reduce field emission. A challenge for the FRIB cavities is the relatively weak fundamental power coupler (FPC) coupling strength (chosen for efficient continuous-wave acceleration), which produces a lot of mismatch during plasma processing at room temperature. For FRIB QWRs, driving the plasma with higher-order modes (HOMs) is beneficial to reduce the FPC mismatch and increase the plasma density. The first plasma processing trial on a spare FRIB QWR cryomodule was done in January 2024; before-and-after bunker tests showed

a significant increase in the average accelerating gradient for field emission onset after plasma processing. The plasma-processed cryomodule was installed into the FRIB linac in August 2024; the in-situ performance was similar to that of the post-plasma-processing bunker test. Additional development work is ongoing, with the goal of a first in-tunnel plasma processing trial during the summer 2025 linac maintenance period.

Funding Agency:

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Tuesday Oral Session: B - Board: TUB06C / **54**

Plasma processing under the microscope: a multi-diagnostic investigation from langmuir probes to cryogenic RF tests in low-beta SRF cavities

Author: Camille CHENEY[1]

Co-author: David Longuevergne [1]

[1] *Laboratoire de Physique des 2 Infinis Irène Joliot-Curie*

Corresponding Author: camille.cheney@ijclab.in2p3.fr

Plasma processing has emerged as a powerful tool for restoring and sustaining the performance of SRF cavities over long-term operation. While well-established for elliptical cavities, its application to low-beta structures presents new challenges due to their complex geometries. To address this, we developed optimized plasma processing techniques for a quarter-wave resonator (SPIRAL2 QWR) and a single-spoke resonator (PIP-II SSR1), precisely targeting critical regions such as accelerating gaps and multipacting-prone areas.

Despite the increasing adoption of plasma processing, the underlying plasma parameters remain poorly known. At IJCLab, we conducted advanced numerical simulations alongside direct Langmuir probe diagnostics, marking one of the first in-depth characterizations of the plasma parameters in these cavities. In addition, in-situ quartz crystal microbalance (QCM) measurements quantified the cleaning rate, revealing a strong correlation between plasma parameters and carbon-based surface contamination removal efficiency. To validate our approach, vertical cryostat RF tests were performed on an SSR1 cavity before and after processing.

Our findings provide valuable insights into the effectiveness of our plasma processing approach, representing a major step toward fully optimizing this technique for next-generation SRF systems, both in long-term operation and cavity preparation protocols.

Funding Agency:

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Tuesday Oral Session: B - Board: TUB07C / **64**

Study of niobium surface under ultra hight vacuum after heat treatment for SRF cavities

Author: Chahinez Boutelaa[1]

Co-authors: David Longuevergne [2]; Gaël Sattonnay [2]; Philipp Kolb [3]; Robert Laxdal [3]

[1] *Centre National de la Recherche Scientifique*

[2] *Institut National de Physique Nucléaire et de Physique des Particules*

[3] *TRIUMF*

Corresponding Author: chahinez.boutelaa@ijclab.in2p3.fr

Specific heat treatments applied to superconducting radio-frequency (SRF) cavities, such as nitrogen infusion or Mid-T baking, aim to improve the quality factor (Qo) at medium accelerating fields (~10–20 MV/m). These treatments reduce the BCS surface resistance by tuning the mean free path of niobium over a few hundred nanometers, either by diffusing oxygen from the native oxide layer or by diffusing nitrogen after the dissolution of the oxide layer. However, these treatments preclude the usual chemical polishing, as it would reverse the beneficial effects of the heat treatments, making the cavities highly sensitive to surface contamination. In particular, the formation of niobium carbides, which can mask the expected benefits, strongly depends on the annealing conditions, surface preparation, and the material's history. Several hypotheses are considered regarding the origin of carbon: vacuum contamination, surface pollution, or internal migration from the niobium itself, potentially enriched with carbon during previous chemical treatments (BCP, EP).

This work aims to identify the primary source of carbon responsible for niobium carbide growth, using techniques such as X-ray photoelectron spectroscopy (XPS), scanning electron microscopy (SEM), and secondary ion mass spectrometry (SIMS). This study will also help identify the key influencing parameters, in order to better understand and reduce their impact on SRF cavity performance.

Tuesday Poster Session - Board: TUP01 / **239**

Test stand for HELIAC cryomodules at GSI

Author: Thorsten Kuerzeder[1]

Co-authors: Christoph Burandt [2]; Florian Dirk Dziuba [2]; Julian List [1]; Maksym Miski-Oglu [2]; Stepan Yaramyshev [2]; Szymon Kowina [2]; Viktor Gettmann [2]; Winfried Barth [2]

[1] *Helmholtz Institute Mainz*

[2] *GSI Helmholtz Centre for Heavy Ion Research*

Corresponding Author: t.kuerzeder@gsi.de

The Helmholtz Linear Accelerator HELIAC is a superconducting (sc) continuous wave linear accelerator for heavy ions currently under development at GSI in Darmstadt. In order to fully test the new cryomodules a new area was set up. The construction started already in 2018 by clearing the necessary space for a radiation protection bunker near the existing pre-accelerator HLI at GSI. Because of a separate beam line from HLI, HELIAC cryomodules can already be tested with beam, which is crucial as the beam dynamics have to be checked, too. The bunker houses now the first 5 m long HELIAC cryomodule, the differential vacuum pumping chambers and the beam diagnostics. In 2021 the set-up of the cryogenic supply was finished. A 80 m long transferline between the cryogenic plant of GSI and a coldbox next to the bunker were installed for the supply with 4 K and 50 K helium. In the same year a first cryogenic test with the cryomodule was done, using dummy cavities. In 2023 the same module was operated, fully equipped with all srf cavities and sc solenoids, with beam. We will report on the details of the set-up and its installation.

Tuesday Poster Session - Board: TUP02 / **343**

Application of the plasma processing technique to the ELBE SRF gun

Author: Andre Arnold[1]

Co-authors: Adrian Hoffmann [1]; Max Henryk Berndt [1]; Petr Murcek [1]

[1] *Helmholtz-Zentrum Dresden-Rossendorf*

Corresponding Author: a.arnold@hzdr.de

As for all superconducting radio-frequency (SRF) cavities preserving the performance during accelerator operation is even more essential for an SRF gun, because the accelerating field is typically very high and cannot be compensated by a neighboring cavity. One of the main limiting factors remains field emission, that is originating either from particulates or hydrocarbon contaminants on the niobium surface. To remove the latter, plasma cleaning was developed for the Spallation Neutron Source (SNS) at the Oak Ridge National Laboratory as an effective method for mitigating field emitters and increasing the work function of Nb. For elliptical cavities, the method was then adapted by Thomas Jefferson National Accelerator Facility for their 1.5 GHz CEBAF cavities and later further developed by Fermi National Accelerator Laboratory for the 1.3 GHz TESLA design. Since the ELBE SRF gun cavity is also based on an elliptical design with the same resonant frequency, a similar experimental setup was built to adapt the published results to a 3.5-cell test cavity made from reactor grade Nb (RRR40). The contribution will present a detailed description of the plasma processing setup as well as RF simulations and measurements of the 1st and 2nd dipol passband. First plasma ignition was achieved using 100 mbar helium and up to 100 W of RF power but further optimization of the parameter space is needed.

Tuesday Poster Session - Board: TUP03 / **182**

Design, fabrication, assembling and testing of QWR/HWR cryomodules for HIAF project

Author: Feng Bai[1]

Co-authors: Xiaofei Niu [2]; Yuan He [2]; Zhijun Wang [2]

[1] *Institute of Modern Physics*

[2] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: feng9255@impcas.ac.cn

The QWR/HWR cavity cryomodules have been designed for High Intensity heavy-ion Accelerator Facility (HIAF) at the Institute of Modern Physics (IMP) of the Chinese Academy of Science (CAS). There are 17 cryomodules operating at 2 K&3130 Pa of HIAF linac, which consist of 6 QWR007 cryomodules and 11 HWR015 cryomodules, respectively. These cryomodules are being processed in the vendor currently. And the first cryomodule has completed horizontal testing in July 2024. This paper will report the design, fabrication, assembling and testing of the cryomodule for HIAF project.

Tuesday Poster Session - Board: TUP04 / **155**

Cavity compensation studies in the JAEA-ADS superconducting linac using LightWin

Author: Bruce Yee-Rendon[1]

Co-authors: Adrien Plaçais [2]; Frédéric Bouly [2]; Fujio Maekawa [1]; Jun Tamura [1]; Shin-ichiro Meigo [1]; Yasuhiro Kondo [1]

[1] *Japan Atomic Energy Agency*

[2] *Laboratoire de Physique Subatomique et de Cosmologie*

Corresponding Author: byee@post.j-parc.jp

High-intensity accelerators, particularly Accelerator-Driven Systems (ADS), require high availability and reliability for proper operation. For superconducting linear accelerators, the ability to continue operating even when one of the RF cavities fails is key to achieving the required availability, known as cavity compensation. Beam dynamics studies of the JAEA-ADS linear accelerator have demonstrated the possibility of operating with multiple RF cavities disabled with acceptable beam quality. Several other superconducting linear accelerator laboratories have adopted similar methods and developed their procedures. Among these efforts, the LightWin tool has proven to be an effective tool for automatically and systematically identifying compensation settings for each cavity failure in any linear accelerator. This software has been successfully utilized on the MINERVA linac, as well as on the high-energy part of the JAEA-ADS linac. It has currently been tested and improved to ease SPIRAL2 operation. This work presents an analysis of cavity compensation in the JAEA-ADS superconducting linear accelerator using the LightWin tool and compares the results with previous studies.

Tuesday Poster Session - Board: TUP05 / **163**

Three years of operating the superconducting linac for the Linac Coherent Light Source (LCLS)

Author: Sebastian Aderhold[1]

[1] *SLAC National Accelerator Laboratory*

Corresponding Author: aderhold@slac.stanford.edu

The LCLS-II project has installed a new superconducting linac at SLAC National Accelerator Laboratory to enable free electron laser science at repetition rates up to 1 MHz. The installed 35 1.3 GHz cryomodules produce an electron beam with energy of up to 4 GeV. Commissioning of the superconducting linac began in mid-2022, leading to the achievement of first light in 2023 and subsequent user experiment deliveries in 2024.

This poster will provide an overview of the operational experience gained during the three years of operations, focusing on the performance of the superconducting radiofrequency (SRF) cavities and associated systems in the linac. Highlighted topics include beam stability, cavity availability and failure modes, as well as performance improvements in preparation for the installation of the LCLS-II High Energy (HE) Upgrade. Additionally, we will discuss challenges faced, such as power outages, and address degradation mechanisms, including field emission.

Tuesday Poster Session - Board: TUP07 / **235**

LCLS-II-HE cavity and cryomodule test performance

Author: James Maniscalco[1]

[1] *SLAC National Accelerator Laboratory*

Corresponding Author: jamesm@slac.stanford.edu

The LCLS-II-HE project has completed qualification testing of the 9-cell 1.3 GHz cavities and has completed construction and testing of 22 out of 24 new cryomodules. All but 9 cavities out of over 200 tested have met the qualification requirements in vertical test. The cryomodules have met specifications, exceeding the required accelerating voltage by an average of 25 MV per module. Here we present details of these results and an outlook to the final testing stages and installation plans.

Tuesday Poster Session - Board: TUP08 / **216**

Beam characterization and lessons learned from beam commissioning prior to SRF linac integration

Author: Jibong Hyun[1]

Co-authors: Akihiko Mizuno [2]; Ken Takayama [3]; Kai Masuda [1]; Keitaro Kondo [1]; Francesco Scantamburlo [4]; Yann Carin [5]; Herve Dzitko [5]; IFMIF/EVEDA Integrated Project Team [6]

[1] *National Institutes for Quantum Science and Technology*

[2] *Japan Synchrotron Radiation Research Institute; National Institutes for Quantum Science and Technology*

[3] *High Energy Accelerator Research Organization*

[4] *IFMIF/EVEDA Project Team*

[5] *Fusion for Energy*

[6] *IFMIF/EVEDA Integrated Project Team*

Corresponding Author: hyun.jibong@qst.go.jp

The Linear IFMIF Prototype Accelerator (LIPAc) is a deuteron linear accelerator (linac) designed to validate the acceleration of a 125-mA beam up to 9 MeV in continuous wave (CW) operation, contributing to the realization of the IFMIF project. The 125-mA deuteron beam is initially accelerated to 5 MeV by a radio-frequency quadrupole (RFQ) and subsequently to 9 MeV by a superconducting radio-frequency (SRF) linac. In LIPAc, even slight particle losses can lead to SRF linac quenching, component damage, and radioactivation. Therefore, ensuring stable beam transport with minimal particle losses is crucial to the success of this project. LIPAc is assembled and commissioned in phases, and the installation of the SRF linac into the beamline is underway. The validation of the functionality of the beam diagnostic devices and the characterization of the beam properties were conducted during phase B+ beam commissioning prior to operating with the SRF linac. Particle losses and discrepancies were observed between the measured and simulated beam sizes. However, through iterative optimization, these particle losses were minimized achieving a matched beam. In this conference, the details of the beam characterization and lessons learned from Phase-B+ will be presented, as well as the beam optics for commissioning with the SRF linac.

Tuesday Poster Session - Board: TUP09 / **4**

Point contact tunneling spectroscopy for SRF applications

Author: Ivana Curci[1]

[1] *Université Paris-Saclay*

Corresponding Author: curciivana@gmail.com

Point Contact Tunneling Spectroscopy (PCTS) is a powerful technique ideal for investigating the surface superconducting properties of materials. Since it utilizes the oxides present on the sample' s surface to probe the superconducting density of states, this tool is valuable for studying superconducting devices such as qubits and SRF cavities, where a native or engineered oxide layer is present on the surface. PCTS can uncover various phenomena at the oxide/superconductor interface, such as the presence of magnetic impurities or the proximity effect, which might play a significant role in the performance limitations of superconducting devices. Therefore, PCTS is highly useful for understanding the mechanisms that limit the capabilities of these devices, potentially leading to technological solutions. I will present our latest PCTS results obtained on Nb, Nb3Sn and NbTiN samples for RF applications.

Tuesday Poster Session - Board: TUP10 / **79**

Identifying the connections between grain growth and flux expulsion in low RRR niobium SRF cavities

Author: Katrina Howard[1]

Co-authors: Daniel Bafia [2]; Zuhawn Sung [2]; Wieslawa Dziedzic-Misiewicz [2]; Young-Kee Kim [3]

[1] *University of Chicago*

[2] *Fermi National Accelerator Laboratory*

[3] *University of Chicago; Fermi National Accelerator Laboratory*

Corresponding Author: khoward99@uchicago.edu

The SRF community has shown that high temperature annealing can improve the flux expulsion of niobium cavities during cooldown. The required temperature will vary between cavities and different batches of material, typically around 800 C and up to 1000 C. However, for niobium with a low residual resistance ratio (RRR), even 1000 C is not enough to improve its poor flux expulsion. The purpose of this study is to observe the grain growth behavior of low RRR niobium coupons subjected to high temperature annealing to identify the mechanism for improving flux expulsion. We observe that low RRR material experiences less grain growth than high RRR when annealed at the same temperature. We search for the limitations to grain growth in low RRR material and develop a diagnostic based on grain structure to determine the appropriate recipe for good flux expulsion. The results of this study have the potential to unlock a new understanding on SRF materials and enable the next generation of high Q/high gradient surface treatments.

Funding Agency:

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Tuesday Poster Session - Board: TUP11 / **108**

Development of in situ thickness sensor for vapor diffused Nb3Sn films

Author: Katrina Howard[1]

Co-authors: Grigory Eremeev [2]; Sam Posen [2]; Brad Tennis [2]; Daniel Bafia [2]; Young-Kee Kim [3]

[1] *University of Chicago*

[2] *Fermi National Accelerator Laboratory*

[3] *University of Chicago; Fermi National Accelerator Laboratory*

Corresponding Author: khoward99@uchicago.edu

Fermilab is one of the leaders in development of vapor diffused Nb3Sn films inside niobium cavities. This material has a higher critical temperature (Tc) than niobium, enabling cavity operation at 4.2 K. This higher operational temperature significantly reduces the infrastructure required for cooling compared to 2 K systems, making superconducting radio-frequency (SRF) technology more accessible. Current deposition methods have relied on iterative testing to determine nominal film thickness, a process that can be time-consuming and imprecise. To address this, we are developing a sensor to measure the thickness of Nb3Sn thin film in situ during vapor diffusion. Our design involves the resistance measurement of a thin film of niobium. During coating, the change in resistance reflects the conversion of the film to Nb3Sn, which allows simple integration with the current furnace infrastructure. This sensor would allow real time measurement of the thickness, allowing for increased precision in future depositions.

Funding Agency:

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Tuesday Poster Session - Board: TUP12 / **344**

Evolution of the ELBE SRF gun - improvements towards the 3rd generation

Author: Petr Murcek[1]

Co-authors: Adrian Hoffmann [1]; Andre Arnold [1]; Anton Ryzhov [1]; Gowrishankar Hallilingaiah [1]; Jochen Teichert [1]; John Vennekate [2]; Max Henryk Berndt [1]; Rong Xiang [1]; Shuai Ma [3]; Stefan Gatzmaga [1]

[1] *Helmholtz-Zentrum Dresden-Rossendorf*

[2] *Thomas Jefferson National Accelerator Facility*

[3] *China Academy of Engineering Physics, Institute of Applied electronics*

Corresponding Author: p.murcek@hzdr.de

HZDR has done pioneering work in the field of the superconducting photoelectron source (SRF gun). The development began more than 20 years ago with the first proof of concept experiment. This was the first time worldwide that electrons were generated from a normal-conducting semiconductor photocathode within a superconducting half-cell resonator [1]. Convinced by this success the work was continued by developing a 3½-cell prototype SRF gun (referred to as ELBE SRF gun I). During an operating time of about 5 years, various problems were solved and different routines were implemented, which finally made it possible to drive the free-electron laser of the ELBE accelerator by the SRF gun [2]. In order to take full advantage of the electron source an improved niobium cavity was built and together with a superconducting solenoid integrated in a new gun module (referred to as ELBE SRF gun II). Since 8 years this gun is in routine user operation, delivering bunches with 200 pC and a repetition rate of 100 kHz to generate THz radiation in a very stable and reliable manner [3]. The development of the third generation of this electron source is now concentrating on the cathode cooler, the cathode transfer system and the superconducting solenoid, while the cavity was refurbished with the help of HZB in Berlin. The contribution will present the lessons learned and the main technical changes of ELBE SRF gun III compared to its predecessors.

Footnotes:

[1] D. Janssen et al., Nucl. Instr. Meth. A 507 (2003) 314 - 317
[2] J. Teichert, et al., Nucl. Instr. Meth. A 743 (2014) 114 - 120
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Tuesday Poster Session - Board: TUP13 / **75**

Mechanically polishing electroplated Nb3Sn for higher accelerating gradients

Author: Liana Shpani[1]

Co-authors: Grigory Eremeev [2]; Matthias Liepe [3]; Sam Posen [2]

[1] *Cornell University (CLASSE)*

[2] *Fermi National Accelerator Laboratory*

[3] *Cornell University*

Corresponding Author: ls936@cornell.edu

As the demand for more efficient SRF technology continues to rise, so does the need to improve the performance of Nb3Sn, the most promising alternative to niobium. Leveraging recent breakthroughs in Nb3Sn research from Cornell University and Fermilab, namely the electrochemical synthesis-based growth of Nb3Sn and the centrifugal barrel polishing (CBP) technique to smoothen the final Nb3Sn film, our primary goal is to reduce surface roughness while preserving the film's quality. We present promising RF results from an electroplated cavity that underwent mechanical polishing using the CBP technique, which showed an increase in the maximum accelerating gradient compared to the baseline test.

Tuesday Poster Session - Board: TUP14 / **88**

Measurements of the DC field of first vortex penetration on modern SRF materials using a vibrating sample magnetometer

Author: Lucas Wallace[1]

Co-author: Tobias Junginger [2]

[1] *University of Victoria*

[2] *TRIUMF*

Corresponding Author: lucasw@uvic.ca

A vibrating sample magnetometer (VSM) is being developed with the capability to measure field penetration on ellipsoidal superconducting samples intended for use in superconducting radio frequency cavities. The explicit goal of this machine is to perform field penetration measurements on atomic layer deposition (ALD) coated niobium ellipsoids (ie., thin film MgB2, Nb3Sn on Nb), as well as on electropolished (EP) bare/low-temp baked Nb, and pair these measurements with beta detected nuclear magnetic resonance (bNMR) measurements on identical samples. The machine is capable of performing field penetration measurements at temperatures as low as ~2 kelvin, and for magnetic fields up to ~450 mT. Additionally, the test stand is based around a 1.5 watt SHI cryocooler, and is thus helium free. To accompany the VSM, an in-house EP setup for both flat and ellipsoidal Nb samples has begun development. This EP test stand, along with the vacuum furnace located at TRIUMF,

will allow production of highly polished bare/baked Nb ellipsoids for field penetration measurements. The flat samples then provide a witness to the EP process in order to characterize the post-EP surface roughness. These combined facilities are well suited to measure field penetration on a wide range of modern SRF materials, encompassing ALD thin films, multilayers, and low-temperature baked niobium samples.

Tuesday Poster Session - Board: TUP15 / **258**

Predicting the critical fields of the vortex state in impure superconductors

Author: Lucas Wallace[1]

[1] *University of Victoria*

Corresponding Author: lucasw@uvic.ca

Here we investigate the magnetic phase behaviour of an impure superconductor, and predict the critical fields of the Meissner/vortex state in the presence of impurities. To do this, we derive the Gibbs free energy of an impure superconductor immersed in an external magnetic field. We then use this Gibbs free energy to derive modified Ginzberg-Landau equations, which if solved describe the equilibrium state of the superconductor. We go on to solve these modified Ginzberg-Landau equations numerically, and use these solutions to predict the energy barrier for transition between the Meissner and vortex states. We perform this calculation in the case of a superconductor-insulator boundary, which has practical applications in superconducting radio frequency cavities. Operating in the Meissner state is critical for superconducting radio frequency cavities, thus calculating this state's stability is an important practical problem. Additionally, it has been theorized that some of the most promising surface treatments for cavities work due to diffusion of oxygen impurities into the superconductor, which "dirty" the material. Understanding the action of some general impurity distribution on the stability of the Meissner state could then lead to higher critical fields and more efficient superconducting radio frequency cavities.

Tuesday Poster Session - Board: TUP16 / **278**

Quality factor analysis of surface-passivated cavities at low gradients applying two level system models

Author: Rakshith Venugopal[1]

Co-authors: Getnet Kacha Deyu [2]; Marco Voige [2]; Karol Kasprzak [1]; Mateusz Wiencek [1]; Robert H. Blick [3]; Wolfgang Hillert [2]; Hans Weise [1]; Marc Wenskat [2]

[1] *Deutsches Elektronen-Synchrotron DESY*

[2] *Universität Hamburg*

[3] *Center for Hybrid Nanostructures*

Corresponding Author: marc.wenskat@desy.de

The native oxides of niobium cause surface losses during cavity operation arising from two-level systems/defects (TLS). These losses dominate the quality factor at low accelerating gradients (Eacc < 0.1 MV/m). In particular, the amorphous Nb2O5 is identified as a prominent host for the TLS. Nb2O5 dissociates when the material is baked above 200 ℃ for several hours in vacuum (the so-called Mid-T Bake), allowing for the modification or reduction of these losses. However, due to the

inevitable exposure to air after the annealing, the surface reoxidizes and Nb2O5 regrows. When the cavity is already coated with Al2O3 or Ta2O5 and then subjected to the Mid-T Bake, this subsequent reoxidation of the niobium is inhibited.

It is still unclear how the TLS losses are modified when the surface undergoes a passivating coating, and this study aims at possibly finding a correlation between the different passivating layers.

Herein, we studied the quality factor of several superconducting radio frequency cavities in the low gradient range (Eacc < 0.1 MV/m) at 1.5 K and analyzed the data using TLS models like the standard TLS model and the non-interacting TLS (one species and two species). Specifically, we used cavities that had undergone the standard "European XFEL"treatment, followed by an atomic layer depositing coating with a passivating layer and the subsequent Mid-T Bake.

Tuesday Poster Session - Board: TUP17 / **89**

Characterization of multilayer SRF cavity materials using radioactive beam based techniques for gradient enhancement

Author: Md Asaduzzaman[1]

Co-authors: Ryan M. L. McFadden [2]; Edward Thoeng [3]; Anne-Marie Valente-Feliciano [4]; David R. Beverstock [4]; Andreas Suter [5]; Zaher Salman [5]; Thomas Prokscha [5]; Yasmine Kalboussi [6]; Thomas Proslier [7]; Ruohong Li [8]; Gerald D. Morris [8]; Sarah R. Dunsiger [8]; W. Andrew MacFarlane [3]; Robert Laxdal [8]; Tobias Junginger [2]

[1] *University of Victoria*

[2] *TRIUMF; University of Victoria*

[3] *TRIUMF; University of British Columbia*

[4] *Thomas Jefferson National Accelerator Facility*

[5] *Paul Scherrer Institute*

[6] *Commissariat à l'Energie Atomique*

[7] *Université Paris-Saclay*

[8] *TRIUMF*

Corresponding Author: asadm@uvic.ca

Coating Nb with thin superconducting layers (with or without insulating layers, i.e., SS or SIS) with longer penetration depth λ can enhance the accelerating gradient by maintaining the Meissner state above each layer's superheating field Bsh, due to reduced surface screening currents and interfacial energy barriers. We review previously published studies using radioactive beam-based techniques to investigate SS and SIS for increasing accelerating gradient. Muon spin rotation (μSR) measurements of Nb3Sn(2 μm)/Nb samples revealed interfacial energy barriers through depth profiling of the first-flux-penetration field Bvp, consistent with Nb's metastable Bsh. Low-energy μSR study at depths <=~ 150 nm in SS Nb1-xTixN/Nb samples confirmed nanoscale current suppression and a bipartite Meissner screening profile, supporting the "counter-current" model and identifying optimal coating thickness for maximizing Bvp. For vortex penetration study in SIS, β-detected nuclear magnetic resonance (βNMR) study optimizes the superconducting and normal-state properties of Nb0.75Ti0.25N in Nb0.75Ti0.25N(91 nm)/AlN(4 nm)/Nb. Resonance measurements in the vortex state showed broadening below Tc ~ 15 K, yielding λ near the intrinsic limit, while spin-lattice relaxation exhibited a metallic Korringa response modified below Tc by a Hebel-Slichter coherence peak.

Tuesday Poster Session - Board: TUP18 / **104**

Detailed surface morphological studies of Nb_3Sn treated by controllable bipolar pulsed electropolishing

Author: Mingqi Ge[1]

Co-author: Hui Tian [1]

[1] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: mingqi@jlab.org

Post-coating surface treatment is a crucial approach for eliminating surface flaws and enhancing the RF performance of Nb_3Sn. The bipolar pulsed electropolishing (BPEP) technique, originally developed for Nb, is adaptable to Nb_3Sn and offers precise, controllable surface removal at slow rates—an essential feature for this application. In BPEP, the net removal rate is proportional to the repetition frequency and can be controlled with nanometer-scale precision, down to a few angstroms per pulse. The BPEP process enables highly controlled surface finishing by engineering the anodic/cathodic potential and pulse duration. Adjusting these parameters in response to surface morphology changes can further optimize the process. Our systematic BPEP morphology studies on Nb samples demonstrate that removal rate and uniformity can be finely tuned. The advantages of BPEP for Nb_3Sn extend beyond Sn vapor-diffusion deposited Nb_3Sn/Nb cavities; it is a versatile technique applicable to any Nb_3Sn-coated SRF cavity, offering a promising path for improving surface quality and RF performance.

Tuesday Poster Session - Board: TUP19 / **58**

Development of a 1.3 GHz RF research cavity for use in testing of superconducting thin films

Author: Nathan Leicester[1]

Co-authors: Graeme Burt [2]; Oleg Malyshev [2]; Daniel Seal [2]; Reza Valizadeh [2]; Christopher Benjamin [2]; Amir Mogheyseh [2]; Bhagat-Taaj Sian [2]; Maleesh Dissanayake Mudiyanselage [3]; James Conlon [2]; Cristian Pira [4]; Eduard Chyhyrynets [4]

[1] *Cockcroft Institute*

[2] *Science and Technology Facilities Council*

[3] *Lancaster University*

[4] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: nathan.leicester@cockcroft.ac.uk

RF testing is a key element in the development of superconducting thin film coated cavities. Initially RF tests are performed for thin film coatings on planar copper disks, before moving to cavities. To further progress in understanding the thin film deposition process, a new RF cavity has been designed, optimized specifically for use in thin film testing. This cavity serves as an intermediary research cavity, bridging the gap between flat samples and accelerating cavities. The cavity is split longitudinally, giving it an open-faced design, that enables a larger variety of deposition processes (including facilities designed for planar samples), as well as facilitating easy access for surface observation, measurement and quality control of the deposited films. Furthermore, it has been designed to minimize the surface electric field to below 13 MV/m at 80 mT. This allows for a multi-step approach to thin film testing, where the first step shows the surface resistance of the cavity from only the change in the magnetic field, while avoiding unwanted additional effects such as field emissions. Once deposition parameters are optimised these can then be applied to traditional cavities. This paper discusses the optimisation of this novel cavity geometry for use in thin film testing, as well as showing the results of testing a range of superconducting thin film materials deposited onto longitudinally split RF cavities.

Tuesday Poster Session - Board: TUP20 / **82**

Density-functional theory study of novel recipes to reduce Nb3Sn grain boundary dissipation

Author: Nathan Sitaraman[1]

Co-author: Matthias Liepe [1]

[1] *Cornell University*

Corresponding Author: nss87@cornell.edu

Previous research has shown that Nb3Sn cavities with tin-rich grain boundaries tend to show significant Q-slope behavior, while cavities with grain boundaries of the "ideal"25 %-tin composition have higher quality factors and reach higher quench fields. In this paper, we make the case that it is possible to improve the properties of Nb3Sn grain boundaries even further. We use density-functional theory (DFT) to show that the addition of some ternary elements creates Nb3Sn grain boundaries with more bulk-like electronic structure, potentially making them more resistant to magnetic flux entry and dissipation. We discuss next steps toward introducing ternary elements in a post-processing step compatible with existing state-of-the-art Nb3Sn cavity recipes.

Funding Agency:

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Tuesday Poster Session - Board: TUP21 / **304**

Progress on theory of nanohydride dissipation

Author: Aiden Harbick[1]

Co-authors: Mark Transtrum [1]; Matthias Liepe [2]; Nathan Sitaraman [3]

[1] *Brigham Young University*

[2] *Cornell University (CLASSE)*

[3] *Cornell University*

Corresponding Author: nss87@cornell.edu

We present further progress on a theoretical model linking nanohydride formation to mid- and high-field Q-slope in SRF cavities. Using time-dependent Ginzburg-Landau theory, we calculate Q-vs-E curves for cavities with a range of hydride distributions corresponding to different global hydrogen concentrations and different distributions of hydride nucleation sites. We show that hydrides smaller than one coherence length in radius have a minor effect on dissipation, even at high fields and high overall hydrogen concentrations. In contrast, hydrides significantly in excess of one coherence length in radius tend to invite flux vortex nucleation and significantly reduce quality factor even at modest fields and lower overall hydrogen concentrations. We conclude that disorder induced by other dissolved impurities may serve to increase the number of hydride nucleation sites, reducing the typical size of nanohydrides beneath the critical coherence length threshold and improving high-field quality factor.

Tuesday Poster Session - Board: TUP24 / **153**

Field emission analysis in SRF cavities for PIP-II using GEANT4

Author: Sajini Wijethunga[1]

Co-authors: Alexander Sukhanov [1]; Kellen McGee [1]; Olivier Napoly [1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: kem11235@fnal.gov

Field emission (FE) remains a significant hurdle for achieving optimal performance and reliability in superconducting radiofrequency (SRF) cavities used in accelerator cryomodules. A thorough understanding of the generation and propagation of FE-induced radiation is therefore essential to mitigate this problem. The absence of standardized measurement protocols further complicates the comparison of radiation data across different testing phases and facilities. This highlights the need for a precise quantitative method to diagnose and analyze FE-induced radiation. Such efforts could prove beneficial for improving cavity preparation and cleanroom assembly techniques during the prototype and production stages of Fermilab's upcoming PIP-II project. In this study, we combine radiation diagnostics with detailed Geant4 simulations to analyze FE-induced radiation, enhance diagnostic accuracy, and optimize detector positioning. This integrated approach ultimately aims at optimizing the preparation, assembly, and testing procedures for PIP-II SRF cavities to achieve FE-free cryomodules.

Tuesday Poster Session - Board: TUP25 / **274**

Localization of field emission emitters in RAON HWRs using quality factor

Author: Sungmin Jeon[1]

Co-authors: Heetae Kim [2]; JangMin Han [2]; Juwan Kim [2]; Yoochul Jung [2]; Youngkwon Kim [2]

[1] *Kyungpook National University*

[2] *Institute for Basic Science*

Corresponding Author: jsminhi@ibs.re.kr

Field emission (FE) is one of the main issues limiting the performance of superconducting cavities. Various studies have been conducted to mitigate FE using methods such as computer simulations, microscopic surface analysis, plasma processing, and X-ray or temperature mapping. Among these, X-ray and temperature mapping are the most direct methods for localizing FE emitters. However, due to limitations such as cavity geometry and construction schedules, installing X-ray or temperature mapping system in the RAON Half-Wave Resonators (HWRs) was limited. To address these challenges, this study investigates the FE characteristics of superconducting cavities by primarily utilizing quality factor measurements, without relying on mapping systems. A new parameter was introduced, derived from the field enhancement factor and onset accelerating field, by processing quality factor data to identify the emitter locations. As a result, several FE-related characteristics in RAON HWRs were identified, including changes in emitter behavior due to FE conditioning and the predominant regions where emitters are likely to be located. Surface regions that require focused treatment to reduce FE were identified as well.

Tuesday Poster Session - Board: TUP26 / **284**

Statistical analysis of field emission for SHINE project

Author: Yue Zong[1]

Co-authors: Jiani Wu [2]; Jinfang Chen [1]; Lijun Lu [2]; ShenJie Zhao [3]; Shuai Xing [2]; Xiaohu Wang [4]; Zheng Wang [3]

[1] *Shanghai Advanced Research Institute*

[2] *Shanghai Advanced Research Institute, Chinese Academy of Sciences*

[3] *Shanghai Institute of Applied Physics*

[4] *ShanghaiTech University*

Corresponding Author: zongy@sari.ac.cn

Field emission is one of the main problems that is difficult to completely avoid in superconducting accelerator project construction, and it is usually considered to be caused by particles or foreign materials. Although careful assembly and cleaning can minimize or eliminate this issue, field emission may still occur to some extent. This report focuses on the field emission problem faced by the current SHINE project, including the field emission of bare cavities after surface treatment and of cryomodules after clean assembly. Through statistical analysis, we found some connection between processing and field emission, and we hope that these problems will be gradually solved in the future to improve the field emission-free rate of SHINE cryomodules.

Tuesday Poster Session - Board: TUP27 / **139**

Design and simulation of 975 MHz superconducting radio frequency cavity

Author: Yuxuan Fan[1]

Co-authors: Jinghe Yang [1]; Bo Wang [1]; Han Lei [1]

[1] *China Institute of Atomic Energy*

Corresponding Author: 1393896779@qq.com

The superconducting linac is proposed for effective acceleration of proton beam in a new project of China Institute of Atomic Energy. A 975MHz superconducting radio frequency cavity is designed to accelerate the H+ ion beam in the energy range from 500 MeV to 1000 MeV. This paper will present the design and simulation, including the multi-parameter electromagnetic design and optimization, high-order modes analyses, multipacting simulations, mechanical and engineering analyses. A prototype cavities were fabricated and vertical tested to verify the electromagnetic properties, the fabrication and post-processing technologies.

Tuesday Poster Session - Board: TUP28 / **144**

Optimization of deposition parameters for synthesising Nb3Sn film on copper cavity with and without buffer layer

Author: Christopher Benjamin[1]

Co-authors: Daniel Seal [1]; Reza Valizadeh [1]; Stephane Simon [2]; oleg Malyshev [1]

[1] *Science and Technology Facilities Council*

[2] *University of Liverpool*

Corresponding Author: christopher.benjamin@stfc.ac.uk

In this study, superconducting Nb3Sn films were synthesised on different substrate such as sapphire, diamond turned copper and polished Nb, by DC magnetron sputtering from a single stoichiometric alloy Nb3Sn target. The structural, morphological and superconducting properties of the films were investigated. The effect of different deposition and substrate was examined. The film properties are characterized by X-ray diffraction, scanning electron microscopy, atomic force microscopy, energy dispersive X-ray spectroscopy, and secondary ion mass spectroscopy, X-ray photon spectroscopy. The DC superconducting properties of the films deposited on sapphire are characterized by a four-point probe measurement and squid magnetometer down to cryogenic temperatures. The RF surface resistance and critical temperature of films deposited on copper was measured over a temperature range of 4–23 K using 8.7 GHz choke Nb cavity. As-deposited Nb3Sn films on sapphire had a superconducting critical temperature of 18.26 K for optimum deposition condition. For the films deposited on copper and niobium has Tc of 16.5 K to 19 K , the surface resistance for direct 2.5 μm thick Nb3Sn, on copper was 25μΩ, which increased by two orders of magnitude when deposited on buffer layer of 4 μm thick Nb. Nb3Sn deposited on Nb QPR resulted to surface resistance of 25 nΩ at 1.3 GHz and 4.2 K.

Funding Agency:

STFC

Tuesday Poster Session - Board: TUP29 / **203**

Experimental study on deposition of Nb3Sn thin films on 6 GHz copper half-cell using Co-sputtering

Author: Jiawen Kan[1]

Co-authors: Pei Zhang [1]; Tianmu Xin [1]

[1] *Institute of High Energy Physics*

Corresponding Author: kanjw@ihep.ac.cn

As the application of superconducting cavities becomes increasingly widespread, the development of cost-effective coatings with enhanced performance has become a focal point for researchers. This study primarily focuses on depositing niobium-niobium-tin (Nb3Sn) multilayer thin films on the inner surface of a 6 GHz copper half-cell via the co-sputtering method. The emphasis is on preparing coated superconducting cavities with excellent surface morphology, high quality factor (Q), and high accelerating gradient (Eacc). The copper half-cell is split along its axis, and superior superconducting films are prepared by controlling various co-sputtering conditions, followed by electron beam welding to reassemble the cavity. To date, through sample experiments, we have successfully prepared copper samples coated with Nb3Sn that exhibit a dense surface and a critical temperature (Tc) as high as 17.2 K.

Funding Agency:

IHEP

Tuesday Poster Session - Board: TUP30 / **204**

Towards Nb3Sn coated copper cavities for energy efficient SRF applications

Author: Lambert Alff[1]

Co-authors: Alexey Arzumanov [1]; Amir Farhood [1]; Marton Major [1]

[1] *Technical University of Darmstadt*

Corresponding Author: lambert.alff@tu-darmstadt.de

Superconducting radio frequency (SRF) cavities which are made from bulk niobium and operated at cryogenic temperatures around 2 K, are essential components in modern particle accelerators. Due to the sustainability issues related to niobium, which is considered a critical metal, and the huge power consumption of accelerator facilities, the community has discussed alternative high(er)-temperature superconductors for many years. Recent advances in Nb_3Sn thin film technology have revitalized this discussion. In particular, the ability to coat copper with high-quality Nb_3Sn surface layers has sparked hope that we can finally move beyond conventional niobium technology. We have demonstrated that a specific magnetron co-sputtering process enables the synthesis of fully superconducting Nb_3Sn, even at low temperatures, where copper diffusion can be disregarded. When coating sapphire substrates, we achieve critical temperatures (Tc) of 17.9 K. The same process (i.e. without post-annealing) on copper yields Tc values of around 15 K and lower critical fields of approximately 200 mT at 4 K. Moving beyond flat substrates, we coated a higher order mode (HOM) antenna —a three-dimensional, mushroom-like object —with Nb_3Sn, achieving similar Tc values at all positions on its surface. We anticipate that, by 2030, Nb_3Sn-coated copper cavities will surpass the quality factor of standard Nb bulk cavities.

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Tuesday Poster Session - Board: TUP31 / **229**

Development of a new system for Nb_3Sn thin film deposition on 1.3 GHz cavities

Author: Matteo Lazzari[1]

Co-authors: Alessandro Salmaso [1]; Alex Battistello [1]; Anita Fetaj [1]; Cristian Pira [2]; Davide Ford [1]; Dorothea Fonnesu [2]; Eduard Chyhyrynets [2]; Fabrizio Stivanello [2]; Flavio Pasquato [1]; Oscar Azzolini [1]; Thomas Bortolani [1]

[1] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro*

[2] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: malazzar@lnl.infn.it

Nb_3Sn in the form of thin film on copper is one of the most promising routes in the field of superconducting radio-frequency accelerating cavities for future colliders. At INFN –Legnaro National Laboratories, thin films of Nb_3Sn have been successfully deposited on small copper samples via DC magnetron sputtering the process enabled the production of films with critical temperature > 17 K, at deposition temperatures of 600 ℃ - 650 ℃ and with the implementation of a Nb buffer layer of 30 um thickness. The design and development of a dedicated system to scale this deposition recipe from small samples to a full-size 1.3 GHz copper cavity are presented in this work. The main challenges involve both the high substrate temperatures—requiring careful thermal management and mechanical design—and the need to ensure uniform thin film deposition over a large and curved internal surface. Since a planar magnetron is employed, a rotational motion must be maintained during the process, achieved in this case by rotating the cavity itself. The system's core features include substrate heating using four infrared lamps, the insertion of a custom planar magnetron inside the cavity, and a ferrofluidic rotation mechanism compatible with ultra-high vacuum conditions. To this day, the system has been successfully built and tested.

Tuesday Poster Session - Board: TUP32 / **161**

Research and development of Nb3Sn SRF cavity at IHEP

Author: Peng Sha[1]

Co-authors: Weimin Pan [2]; baiqi liu [1]; Feisi He [1]; song jin [1]; Jinxin Yu [1]; Chao Dong [1]; Zheng Mi [2]; Jiyuan Zhai [1]

[1] *Institute of High Energy Physics*

[2] *Chinese Academy of Sciences*

Corresponding Author: shapeng@ihep.ac.cn

Research of Nb3Sn superconducting radio-frequency (SRF) cavities was conducted at the Institute of High Energy Physics Chinese Academy of Sciences (IHEP), in order to improve the intrinsic quality factor (Q0) and accelerating gradient (Eacc). Various recipes of coating were attempted at SRF cavities and samples made of Nb, which resulted in different Sn content. It was found that the Sn content, namely the ratio of Nb/Sn, had great influences on the performance of Nb3Sn SRF cavities. When the ratio of Nb/Sn was slightly higher than 3, the Nb3Sn SRF cavities showed the best performance during the vertical test. Q0 of 1.3 GHz 1-cell Nb3Sn SRF cavity (the ratio of Nb/Sn ≈ 3.16) reached 3.0 × 1010 (@ 4.2 K) and 1.0 × 1011 (@ 2.0 K) at low RF field. Besides, conduction cooling of Nb3Sn SRF cavity has also been carried out at IHEP.

Tuesday Poster Session - Board: TUP33 / **143**

Results of 1.3 GHz Nb cavity coated with Nb3Sn thin film deposition by PVD magnetron sputtering

Author: Reza Valizadeh[1]

Co-authors: Christopher Benjamin [1]; Daniel Seal [1]; Oleg Malyshev [1]; Stephane Simon [1]

[1] *Science and Technology Facilities Council*

Corresponding Author: reza.valizadeh@stfc.ac.uk

Nb3Sn thin film cavities are new generation of superconducting cavities, which have the potential to replace traditional pure niobium cavities owing to their superior theoretical radio frequency (RF) performance. Higher theoretical acceleration gradient and quality factor give Nb3Sn cavities more possibilities in the future. There have been relatively high success in producing such cavities by Sn diffusion method. The production of such cavities through thin film deposition on copper cavity foresees lower cost of material and at the same time profiting from higher thermal conductance of copper.

At Daresbury Laboratory, we have commissioned a new Nb3Sn deposition facility for depositing a Nb cavity with Nb3Sn. The system is based on using planar magnetron where the optimised parameters for Nb3Sn on flat surfaces had been well stablished. The Cavity was deposited at 580 ℃ using two special designed 2 inch magnetrons travelling inside cavity simultaneously from each end of the

cavity. The deposition was done at 50 W DC power with a bias of -75 V. We further report on the RF performance of the cavity at 4 K in liquid He, demonstrating quality factor Q0 of 3x1010 comparable to Nb cavity at 2 K and extending to accelerating gradient of up to 16 MV/m.

Funding Agency:

STFC

Tuesday Poster Session - Board: TUP36 / **53**

Preparation and test of Nb3Sn film cavities by tin vapor method at Peking University

Author: Ziyu Wang[1]

Co-authors: Fang Wang [1]; Fei Jiao [1]; Feng Zhu [1]; Gai Wang [1]; Jiankui Hao [1]; Lin Lin [1]; Manqian Ren [1]; Senlin Huang [1]; Shengwen Qvan [1]

[1] *Peking University*

Corresponding Author: numb0923@stu.pku.edu.cn

Researches on preparation of Nb3Sn superconducting cavities has been carried at Peking University. Nb3Sn films were prepared by tin vapor method with a high vacuum furnace. We proposed a coating scheme of 1.3 GHz single cell Nb3Sn cavity with three tin sources inside. Nb3Sn films with a tin content of more than 25 % were obtained. The vertical tests show the Q of the prepared Nb3Sn cavities reaches 3.2E10 at low accelerating gradient and larger than 1.0E10@10 MV/m after optimization of the annealing procedure.

Tuesday Poster Session - Board: TUP37 / **81**

Development of plasma processing of 1.3 GHz superconducting radiofrequency cavities at TRIUMF

Author: Daniel Hedji[1]

Co-authors: Philipp Kolb [1]; Robert Laxdal [2]; Tobias Junginger [3]; Vladimir Zvyagintsev [1]; Zhongyuan Yao [1]

[1] *TRIUMF*

[2] *TRIUMF; University of Victoria*

[3] *University of Victoria; TRIUMF*

Corresponding Author: dhedji@triumf.ca

Superconducting Radio Frequency (SRF) technology is a key component in many particle accelerators operating in a continuous wave, or high duty cycle, mode. The on-line performance of SRF cavities can be negatively impacted by the gradual reduction in the accelerating gradient that can be attained within a reasonable field emission level. Conventional cleaning procedures are both time- and resource-exhaustive as they are done ex-situ. Plasma processing is an emerging in-situ method of cleaning which chemically removes hydrocarbon-based field emitters through plasma. An R&D program is underway at TRIUMF with the goal to develop fundamental power coupler (FPC) driven plasma processing of the installed 1.3 GHz nine-cell cavities in the ARIEL 30 MeV SRF e-LINAC. Processing recipes have been systematically studied in single-cell and multi-cell cavities off-line. The

single-cell studies involved varying the input parameters and testing the effectiveness of the treatment through RGA analysis, while the multi-cell tests focused on understanding ignition behaviors when using the TM_{010} passband. The progress on these developments will be reported.

Tuesday Poster Session - Board: TUP38 / **32**

The plasma processing development for CSNS-II superconducting Linac

Author: Cong Zhang[1]

Co-authors: Ahong Li [1]; Bo Li [1]; Huachang Liu [2]; MengXu Fan [3]; Pei Hua Qu [1]; Qi Yu Kong [2]; Qiang Chen [1]; Wenzhong Zhou [1]; Xiaolei Wu [2]

[1] *Institute of High Energy Physics*

[2] *Dongguan Neutron Science Center*

[3] *University of Science and Technology of China*

Corresponding Author: zhangcong@ihep.ac.cn

As a practical technique to mitigate field emission effect of superconducting cavities on-line, plasma processing has been developed for CSNS-II superconducting Linac. Experimental platform has been set up and experiments of plasma ignited in various cavities with different frequencies have been conducted. The details of the research will be presented in the paper.

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Tuesday Poster Session - Board: TUP39 / **245**

Design and simulation of conductive cooling for radio frequency superconducting cavities

Author: Cong Zhang[1]

Co-author: Zhifan Chen [2]

[1] *Institute of High Energy Physics*

[2] *China Spallation Neutron Source*

Corresponding Author: zhangcong@ihep.ac.cn

The RF accelerating module is crucial for imparting kinetic energy to particle beams in accelerators. Superconducting RF (SRF) technology offers key advantages over conventional room-temperature RF systems, including lower operational costs, reduced beam loss, and higher accelerating power. The superconducting cavity, SRF's core component, requires ultra-low temperatures. While liquid helium cooling meets this need, its complex and expensive infrastructure hinders SRF's widespread adoption. Recent advances in cavity manufacturing have improved quality factors (Q-values) and reduced heat loads to watt levels, enabling alternative cooling methods. This study investigates conduction cooling using compact cryocoolers for a 648 MHz superconducting cavity. Numerical

simulations analyzed two cooling structures, focusing on configuration, material choice, and thermal contact resistance. Results show conduction cooling effectively maintains operational temperatures, with high-purity aluminum outperforming oxygen-free copper as a thermal bridge material. Maintaining thermal contact resistance below 10 K·cm²/W is critical. These findings offer valuable guidance for designing more efficient SRF cooling systems.

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Tuesday Poster Session - Board: TUP40 / **220**

Plasma electrolytic polishing @ INFN: a versatile surface treatment for accelerator components and additive manufacturing

Author: Eduard Chyhyrynets[1]

Co-authors: Cristian Pira [1]; Davide Ford [1]; Dorothea Fonnesu [1]; Fabrizio Stivanello [1]; Giorgio Keppel [1]; Hendrik Hähnel [2]; Michael Mayerhofer [3]; Oscar Azzolini [1]; Tochukwu Emmanuel Ezeaba [4]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *Goethe University Frankfurt*

[3] *Universität der Bundeswehr München*

[4] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro*

Corresponding Author: eduard.chyhyrynets@lnl.infn.it

Plasma Electrolytic Polishing (PEP) is under active development at INFN-LNL as a flexible, environmentally friendly alternative to conventional electropolishing (EP). Since 2019, our research has focused on optimizing PEP for a variety of accelerator-relevant materials and geometries, ranging from standard planar samples to complex components, including parts fabricated via Additive Manufacturing (AM). Unlike EP, PEP uses diluted salt-based electrolytes, avoiding hazardous acids, and allows for high removal rates (up to 30 μm/min for Cu) with low surface roughness (Ra<50 nm). These properties make it highly suitable for applications requiring excellent surface finish and minimal contamination, such as RF structures and vacuum components. This contribution presents an overview of the various developments achieved with PEP at LNL. These include treatments of AM stainless steel and copper structures, inner copper conductors, and Cu drift tubes for LINACs. The synergy between PEP and AM surfaces has also been explored, with promising results indicating the potential for replacing multi-step post-processing chains with a single PEP step. Furthermore, custom electrolytes and process parameters have been developed and patented for multiple metals including Cu, Nb, Al, and stainless steels. The contribution highlights the versatility of PEP across multiple materials and geometries, its scalability, and its prospects for integration into accelerator component manufacturing workflows.

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Tuesday Poster Session - Board: TUP41 / **285**

Plasma processing on low beta SRF elliptical cavities

Author: Elisa Del Core[1]

Co-authors: Daniele Sertore [2]; Angelo Bosotti [2]; Enrico Cenni [3]; Paolo Pierini [4]; Bianca Giaccone [5]; Taha Posos [5]; Sergey Kazakov [5]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *Istituto Nazionale di Fisica Nucleare, Laboratori Acceleratori e Superconduttività Applicata*

[3] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

[4] *European Spallation Source*

[5] *Fermi National Accelerator Laboratory*

Corresponding Author: elisa.delcore@mi.infn.it

Plasma treatment has emerged as an effective method for mitigating field emission and recovering the performance of superconducting radiofrequency (SRF) cavities. A collaborative effort involving CEA, ESS, FNAL, and INFN is currently focused on applying this technique to low-beta elliptical cavities for both the ESS and PIP-II linacs. This paper reports on the ongoing work aimed at developing plasma processing for cavities both installed in cryomodules and assembled for the vertical test. For the ESS cavities, a bead-pull setup has been developed, enabling validation of experimental results against electromagnetic simulations. In parallel, FNAL has conducted simulation studies to identify effective modes for plasma ignition in PIP-II cavities, with experimental work expected to start in the coming months.

Funding Agency:

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Tuesday Poster Session - Board: TUP42 / **209**

RF measurement of plasma electrolytic polished 1.3 GHz full-seamless Nb/Cu cavities

Author: Hayato Araki[1]

Co-authors: Carlota Carlos [2]; Cristian Pira [3]; Eduard Chyhyrynets [3]; Guillaume Rosaz [2]; Masashi Yamanaka [1]

[1] *High Energy Accelerator Research Organization*

[2] *European Organization for Nuclear Research*

[3] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: arakih@post.kek.jp

From the production and testing of Nb/Cu elliptical cavities by hydroforming, it was found that there is a problem of poor surface roughness due to the large plastic deformation of the copper substrate. To improve this problem, we are trying to apply Plasma Electrolytic Polishing (PEP), which has been developed by INFN-LNL. PEP has the features of extremely high polishing speed compared to conventional electrolytic polishing and simplicity of equipment structure since the cathode does not need to be inserted into the cavity. We plan to perform PEP at INFN-LNL and niobium thin film coating at CERN on the 1.3 GHz copper hydroformed cavities provided by KEK, and to measure the RF performance at KEK by September 2025. In this poster presentation, the preparation status and results of the cavity measurements will be reported.

Funding Agency:

Amada Foundation

Tuesday Poster Session - Board: TUP43 / **231**

Development of wet nitrogen doping to improve the performance of half-wave resonators

Author: Yuting Wu[1]

Co-authors: Andrei Ganshyn [1]; Chris Compton [1]; Ethan Metzgar [1]; Kenji Saito [1]; Kyle Elliott [1]; Laura Popielarski [1]; Samuel Miller [1]; Sang-hoon Kim [1]; Spencer Combs [1]; Taro Konomi [1]; Ting Xu [1]; Walter Hartung [1]; Wei Chang [1]; Yoo-lim Cheon [1]

[1] *Facility for Rare Isotope Beams*

Corresponding Author: saito@frib.msu.edu

A new surface treatment method is being developed, wet nitrogen doping, in which nitric acid is added during electro-polishing (EP). In the first trial on a FRIB beta = 0.53 half-wave resonator (HWR), a high quality factor (Q0 = 8E10) was observed at 2 K at low field (accelerating gradient ≤ 0.5 MV/m) without an anti-Q slope. It is known that the Q0 can be increased by shortening the mean free path via surface contamination by oxygen. Low-temperature baking (LTB) can allow oxygen to diffuse into the surface to a depth similar to the RF penetration depth. However, nitrogen cannot diffuse via LTB. Therefore, the mechanism for increasing Q0 with N-doping has not been clearly understood. Moreover, by comparing the behavior of buffered chemical polishing (BCP) processed cavities, it was found that BCP also dopes nitrogen on the SRF surface, and the doped nitrogen hinders the diffusion of oxygen under LTB, making LTB unable to mitigate the high field Q-slope (HFQS).

Funding Agency:

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Tuesday Poster Session - Board: TUP44 / **165**

In-situ plasma processing on low-beta cavities at the Argonne Tandem Linac Accelerator System (ATLAS)

Author: Megan McIntyre[1]

Co-authors: Gary Zinkann [1]; Michael Kelly [1]; Milica Samardzic [2]; Troy Petersen [1]

[1] *Argonne National Laboratory*

[2] *Georgia Institute of Technology*

Corresponding Author: memcintyre@anl.gov

A method to enhance ATLAS low-beta superconducting cavities has been developed at Argonne National Laboratory in collaboration with MSU/FRIB, Fermilab, IJCLab, JLab, and BNL. At the center of the accelerator, a cryostat containing seven 72 MHz QWR installed in 2014 has world-leading performance for ion linacs at v/c~0.1, though performance has been reduced by ~20 % over the past decade due to contaminants. ATLAS operates over 6000 hours annually with a winter maintenance period, during which we aim to recover cavity performance through in-situ plasma processing. Cold testing on a spare 72 MHz QWR before and after fundamental mode plasma processing, using the real ATLAS coupler and an 80:20 Ar/O2 gas mixture, demonstrates remarkable improvements. We present experimental results of plasma processing on the spare cavity in both bench-top test and realistic test-cryostat environments. We include a system developed to prevent plasma formation in the coupler port.

Tuesday Poster Session - Board: TUP45 / **222**

Performance analysis of the ESS SRF cavities from qualification to first operation run

Author: Paolo Pierini[1]

Co-authors: Agnieszka Zwozniak [1]; Artur Krawczyk [2]; Cecilia Maiano [1]; Henry Przybilski [1]; Marek Skiba [1]; Muyuan Wang [1]; Nuno Elias [1]; Philippe Goudket [1]; Emanuele Laface [1]

[1] *European Spallation Source*

[2] *Institute of Nuclear Physics, Polish Academy of Sciences*

Corresponding Author: paolo.pierini@ess.eu

The 82 SRF cavities of the present 2 MW configuration of the ESS Linac have been operated up to their specification during the first technical commissioning run on the temporary beam dump. Operational experience and comparison of cavity performances between vertical tests at the project in kind members and those measured at the cryomodule test stands and in the tunnel is described.

Tuesday Poster Session - Board: TUP46 / **223**

Beam-based measurements on ESS SRF cavities

Author: Paolo Pierini[1]

Co-authors: Agnieszka Zwozniak [1]; Artur Krawczyk [2]; Cecilia Maiano [1]; Emanuele Laface [1]; Henry Przybilski [1]; Marek Skiba [1]; Muyuan Wang [1]; Nuno Elias [1]; Philippe Goudket [1]

[1] *European Spallation Source*

[2] *Institute of Nuclear Physics, Polish Academy of Sciences*

Corresponding Author: paolo.pierini@ess.eu

During the present technical commissioning run of the ESS linac several measurements were taken to extract beam properties (e.g. phase and current) on the base of beam transient induced voltage and comparing with beam diagnostic based measurements.

Tuesday Poster Session - Board: TUP47 / **224**

Status of the qualification campaign of the ESS elliptical cryomodules

Author: Paolo Pierini[1]

Co-authors: Agnieszka Zwozniak [1]; Artur Krawczyk [2]; Cecilia Maiano [1]; Henry Przybilski [1]; Marek Skiba [1]; Muyuan Wang [1]; Nuno Elias [1]; Philippe Goudket [1]

[1] *European Spallation Source*

[2] *Institute of Nuclear Physics, Polish Academy of Sciences*

Corresponding Author: paolo.pierini@ess.eu

All elliptical cryomodules are tested at the ESS Test Stand in Lund before their installation in the linac. In June 2024 21 of the 30 cryomodules have been tested, 8 more are being prepared for test. This contribution presents a review of the testing experience, success rate, non-conformities encountered, and their resolution.

Tuesday Poster Session - Board: TUP48 / **175**

Improvement of performance for Nb/Cu hydroformed full-seamless cavity

Author: Masashi Yamanaka[1]

Co-authors: Guillaume Rosaz [2]; Hayato Araki [1]

[1] *High Energy Accelerator Research Organization*

[2] *European Organization for Nuclear Research*

Corresponding Author: masashi.yamanaka@kek.jp

In order to reduce the cost of superconducting cavities, research has been actively conducted in recent years to realize inexpensive cavities by making the cavity body out of copper and coating the inside with niobium to induce superconductivity. The inner surface of the accelerating cavity must be smooth, and a seamless cavity is ideal as a base for the coating. We came up with the idea of manufacturing a seamless cavity from a single copper pipe, and succeeded in prototyping it by hydroforming. At CERN, a niobium coating with a film thickness of about 5 μm was applied by magnetron sputtering. Electric field performance tests were conducted at KEK, and the accelerating gradient reached 12 MV/m at 4 K and 16 MV/m at 1.85 K. We are currently working on further improvements to improve performance. After hydroforming, the inner surface of the cell becomes rough. We report our efforts to improve the roughness by polishing and to design a new mold to improve the accuracy of the cell shape, and the results of hydroforming.

Tuesday Poster Session - Board: TUP49 / **174**

A novel manufacture of niobium foil cavities

Author: Masashi Yamanaka[1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: masashi.yamanaka@kek.jp

In order to reduce the cost of superconducting cavities, we propose a new method of manufacturing cavities using 0.2 mm thick niobium foil tubes. We came up with the idea of applying a plastic processing technology called elctromagnetic forming (EMF). As a result of a feasibility study, we found that niobium is a difficult material to form by EMF, and experimental results showed that it was almost impossible to form. Therefore, we tried a method of forming niobium by layering copper or aluminum materials called drivers on niobium, and felt that it was possible to form it. We report the experimental results so far.

Tuesday Poster Session - Board: TUP50 / **181**

Fabrication of seamless single-cell copper elliptical cavities through bulk-machining

Author: Alan Saillet[1]

Co-authors: Alice Moros [1]; Ana Teresa Perez Fontenla [1]; Grzegorz Sidorowicz [1]; Jean-Marie Geisser [1]; Karol Scibor [1]; Marco Garlaschè [1]; Michal Kolenic [1]; Romain Ninet [1]; Said Atieh [1]

[1] *European Organization for Nuclear Research*

Corresponding Author: alan.saillet@cern.ch

In the context of future accelerator studies, niobium coating of copper-based cavities plays a key role in achieving an optimal balance between radio-frequency performance and cost-effectiveness.

Recent advancements have focused on the development of bulk-machined elliptical cavities, featuring a seamless, weld-free equator. By optimizing the design of machining tools, the machining strategy and processing parameters, Fabrication of high-quality cavities with excellent shape accuracy and surface finish has been achieved, along with improved repeatability.

This contribution presents the current status of fabrication for such seamless cavities, including the design of the specialized cutting tools. It also explores the relationship between cutting tool parameters, machining conditions and surface integrity, providing a deeper insight into the factors that may influence the future success of niobium coatings.

Tuesday Poster Session - Board: TUP52 / **272**

Status of SRF cavity fabrication in Cavity Fabrication Facility (CFF) at KEK.

Author: Takayuki Saeki[1]

Co-authors: Hitoshi Inoue [1]; Masahiko Hiraki [1]; Takeshi Dohmae [1]; Yuichi Watanabe [1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: takayuki.saeki@kek.jp

We have Cavity Fabrication Facility (CFF) at KEK which is a dedicated facility to fabricate SRF cavities. CFF was constructed in the year 2011 and now it has two Electron-Beam Welding (EBW) machines, a press-forming machine, a lathe, a Chemical-Polishing room, and so on in clean rooms. We have been mainly focusing on the fabrication of 1.3-GHz Nb elliptical 9-cell cavities. Recently we fabricated six single-cell cavities where four of them were made from conventional Fine-Grain (FG) Nb material and two of them were made from the Medium-Grain (MG) Nb material which has the grain-size ranging from sub-mm to mm. We also fabricated three 9-cell cavities where two of them were made from FG Nb material and one of them was made from MG Nb material. The fabrication of MG-Nb 9-cell cavity is the first trial in the world. This presentation reports the updated status of machines and the detailed status of fabrication of cavities in CFF at KEK.

Funding Agency:

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Tuesday Poster Session - Board: TUP53 / **146**

First elliptic cavity fabricated with metallographic polishing

Author: Takeshi Dohmae[1]

Co-authors: Claire Antoine [2]; David Longuevergne [3]; Enrico Cenni [4]; Fabien Eozénou [5]; Gregoire Julien [2]; Luc Maurice [5]; Mael Vannson [3]; Nicolas Gandolfo [3]; Oleksandr Hryhorenko [6]; Sebastien Renard [3]

[1] *High Energy Accelerator Research Organization*

[2] *Université Paris-Saclay*

[3] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

[4] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

[5] *Commissariat à l'Energie Atomique*

[6] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: dohmae@post.kek.jp

The development of an easy and inexpensive Nb sheet preparation process, based on metallographic polishing has been presented earlier [1,2]. The aim is to remove the damage layer issued from the rolling process on the sheet in order to reduce the length of surface treatment on completed cavities. The process has been applied on a QPR sample and tested in RF, without any surface chemistry. Its surface resistance is about 4 times lower that the EP baseline at 414 MHz, 2 K [3]. The first elliptical cavity based on this principle has been produced at KEK, starting with large polished sheets developed in collaboration between IJCLAB, and the company LAMPLAN. We present its 1rst RF test at CEA, with a HF rinsing and a recrystallization treatment at 600 ℃ 10 h, without any chemical etching at first.

Footnotes:

[1] C. Z. Antoine and R. Crooks, "Reducing Electropolishing Time with Chemical-Mechanical Polishing" , in Proc. SRF'09, Berlin, Germany, Sep. 2009, pp. 405-405.
[2] O. Hryhorenko et al., "An innovative approach of surface polishing for SRF cavity applications", Journal of Manufacturing and Materials Processing, 2023. 7(2): p. 62.
[3] O. Hryhorenko et al., "Recent Advances in Metallographic Polishing for SRF Application", in Proc. SRF'23, Grand Rapids, MI, USA, Jun. 2023, pp. 646-650.

Tuesday Poster Session - Board: TUP54 / **302**

CEBAF 2023 linac plasma processing gradient and Qo results

Author: Michael McCaughan[1]

Co-authors: Ramakrishna Bachimanchi [1]; Dakota Christian [1]; Gary Croke [1]; Michael Drury [1]; Kevin Jordan [1]; Tom Powers [1]; George Biallas [2]; Kyle Hesse [1]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Hyperboloid LLC*

Corresponding Author: michaelm@jlab.org

Firmware for the Low-level Radiofrequency (LLRF) systems used in the Jefferson Lab C100 and C75 cryomodules was upgraded to allow for a variable duty factor pulsed mode operation with triggered waveforms available through EPICS. A new type of gaseous helium flow meter that has been under development for the past 2 years was also opportunistically installed in cryogenic return U-tubes of 14 of the cryomodules that were cycled to room temperature during the Spring 2023 accelerator

down. These flow meters were developed under an SBIR project* with Hyperboloid LLC. Stub tuners were also adjusted to improve the loaded-Q of the cavities for better klystron operation range. The combination of these activities allowed for re-commissioning of recently plasma processed cavities with pulsed and continuous wave (CW) Self-Excited Loop with Amplitude and Phase locked (SELAP) gradients measured via the LLRF system. Newly developed software also allowed us to measure Qos with the installed flow meters.

Funding Agency:

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Tuesday Poster Session - Board: TUP55 / **327**

Multipacting analysis of the conditioning box of the 591 MHz SRF cavity fundamental-mode power coupler in EIC

Author: Lin Guo[1]

Co-authors: Alex Zaltsman [1]; Daniel Lukach [1]; Douglas Holmes [1]; Prince-David Malendele [1]; Silvia Verdu-Andres [1]; Wencan Xu [1]

[1] *Brookhaven National Laboratory*

Corresponding Author: wxu@bnl.gov

A fundamental-mode power coupler (FPC) for the 591 MHz superconducting RF (SRF) cavities is currently being designed and prototyped for use in the Electron Storage Ring of the Electron-Ion Collider. Due to limitations in power source availability and in consideration of the FPC fabrication schedule, the initial high-power tests of the prototyped FPCs are planned to be conducted using a 704 MHz power source. The conditioning box to be used has been structurally modified based on the existing design. Multipacting simulations have been carried out for both the FPC and the conditioning box under high-power conditions. The simulation results will be compared with subsequent experimental tests to provide references for future high-power testing at 591 MHz.

Tuesday Poster Session - Board: TUP56 / **173**

Development of organic solvent electropolishing method for Nb cavities

Author: Takeyoshi Goto[1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: gotota@post.kek.jp

Electropolishing (EP) is used for the surface treatment of Nb cavities used in superconducting accelerators. The electrolyte for Nb material EP is a mixture of hydrofluoric acid and sulfuric acid, which makes EP work in Nb cavities very expensive. In this study, the development of a new EP method for Nb cavity using fluoride salts and organic solvents will be reported. The organic solvents with high flash point and high relative permittivity, such as ethylene glycol and formamide were chosen. It was found that an electrolyte solution of ammonium fluoride dissolved in ethylene glycol (2 M) could be used for mirror finish

Tuesday Poster Session - Board: TUP57 / **164**

Preliminary results of electromagnetic and beam dynamics simulation for optimizing an SRF gun cavity to maximize the beam brightness

Author: Gowrishankar Hallilingaiah[1]

[1] *Helmholtz-Zentrum Dresden-Rossendorf*

Corresponding Author: g.hallilingaiah@hzdr.de

A high beam brightness is an important requirement for an electron linear accelerator, with the electron source setting the lower limit for the achievable brightness. A superconducting radio-frequency photoelectron injector (SRF gun)) stands out as an advanced electron source capable of delivering beams with superior properties compared to other continuous-wave injectors. Currently, SRF guns are being reliably operated at various accelerators. However, the gun cavities are operated below its design gradient due to the field emission. This lower gradient reduces particle energy gain per cell and adversely affects beam quality by deviating from theoretical optima.

To overcome these limitations, a new cavity design is being explored, with the peak surface electric field restricted to 30 MV/m, corresponding to the fields that have typically been achieved so far. In the first step, the first half-cell geometry will be optimized to maximize the ratio of the cathode' s electric field to the resonator's surface field (Ecath/Epk) which guarantees the maximum possible acceleration of the electrons from their generation. Following this, additional optimized cells are included to maximize the beam energy gain. Subsequent to the electromagnetic optimization, beam dynamics study will provide the operating point of the SRF gun to maximize the beam brightness. This contribution will discuss the initial findings from the electromagnetic and beam dynamics study.

Tuesday Poster Session - Board: TUP58 / **115**

Status of the SRF cavity tuner for the MEXT-ATD / ITN cryomodule being built at KEK

Author: Mathieu Omet[1]

Co-authors: Ashish Kumar [1]; Kensei Umemori [1]; Rishabh Bajpai [1]; Takeshi Dohmae [1]; Tomohiro Yamada [1]; Toshihiro MATSUMOTO [1]; Yasuchika Yamamoto [1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: mathieu.omet@kek.jp

Currently a prototype cryomodule for the International Linear Collider featuring eight 1.3 GHz TESLA-type superconducting radio frequency cavities is being designed and built at KEK. In this contribution we report on the status of the development and production of the cavity frequency tuner. The design of the tuner body was finalized and the procurement of the first four series units is underway. The first test of the slow actuator cold test setup is discussed. It is prepared for the upcoming qualification of a newly developed slow actuator. Results of the qualification tests of a new fast actuator prototype are presented. The concept of the fast actuator control system is described.

Tuesday Poster Session - Board: TUP59 / **183**

Developments for the RF transmission system for the ITN cryomodule

Author: Prakash Joshi[1]

Co-authors: Mathieu Omet [2]; Shinichiro Michizono [2]; Toshihiro Matsumoto [2]

[1] *The Graduate University for Advanced Studies, SOKENDAI*

[2] *High Energy Accelerator Research Organization; The Graduate University for Advanced Studies, SOKENDAI*

Corresponding Author: prakashj@post.kek.jp

The International Linear Collider (ILC) is a future linear collider using superconducting accelerating cavities. R&D for the radio frequency power distribution system, which will deliver the radio frequency power from the klystrons to the cavities, is ongoing. In scope of the ILC Technology Network (ITN) an ILC prototype CM featuring 8 cavities is developed and built at KEK. The cavities will be driven by a 10 MW multibeam klystron located about 200 m away from the test stand. The klystron delivers its power through two WR650 ports. A magic tee was designed to combine the two klystron outputs into a single waveguide. The waveguides at the cavity input couplers are also of the type WR650. For efficient transmission of the required power over most of the distance a WR770 type waveguide will be used. An adapter for the interconnection of the WR650 and WR770 waveguides was developed. Furthermore, WR770 H and E corners were designed.

Funding Agency:

MEXT Development of key element technologies to improve the performance of future accelerators program (JPMXP1423812204)

Tuesday Poster Session - Board: TUP60 / **117**

Real-time cavity simulator and tuner control system for the ITN cryomodule at KEK

Author: Rishabh Bajpai[1]

Co-authors: Mathieu Omet [1]; Toshihiro MATSUMOTO [1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: bajpai@post.kek.jp

At KEK, an International Linear Collider prototype cryomodule containing eight TESLA-type cavities is currently under development and is scheduled for testing in 2028. To evaluate the performance of the low-level RF (LLRF) system, a Red Pitaya-based cavity simulator is being developed. The simulator will also be used at the STF VT stand to support the development of the digital LLRF system, which is necessary for preparation of the Vertical Tests for the ITN CM cavities. Additionally, we are considering utilizing the Red Pitaya hardware platform to control the piezo of the cavity tuners for Lorentz force detuning (LFD) compensation. In this contribution the progress of the cavity simulator and tuner control are reported. Furthermore, results from electromagnetic and mechanical simulations of the ITN cavities, used to determine the Lorentz force detuning constant and pressure sensitivity are reported.

Tuesday Poster Session - Board: TUP61 / **255**

Design study of a cryomodule that meets ILC requirements at KEK

Author: Takafumi Hara[1]

Co-authors: Kensei Umemori [1]; Takeshi Dohmae [1]; Tomohiro Yamada [1]; Yasuchika Yamamoto [1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: thara@post.kek.jp

A 5-year project called MEXT Advanced Accelerator element Technology Development began in FY2023 at KEK. The goal of this project is to manufacture one cryomodule (CM) that meets the requirements of International Linear Collider (ILC) and to test completed CM at cryogenic temperature. ILC model CM consists of nine cell superconducting cavities, magnetic shields, power couplers, tuners, cooling piping to cool the cavities to 2 K, two layers of thermal shields cooled to 80 K and 5 K respectively, a superconducting magnet and a beam position monitor. In this development, we are also aiming to reduce the manufacturing costs of the CM. Two layers of thermal shield in ILC model CM were changed to single layer thermal shield in the KEK design to reduce costs and to simplify the structure. Pipes which are compliant with JIS (Japanese Industrial Standard) and easy to procure in Japan will be used in this CM. For the cooling test, the placement of temperature sensors on each component was considered. The feedthroughs were newly designed for various sensors, monitors and power supplies. This development will contribute to establish technologies of superconducting accelerator and is a step toward the realization of the ILC. This presentation will report on the status of designing and manufacturing of the CM.

Funding Agency:

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Tuesday Poster Session - Board: TUP62 / **243**

Specification, design, production including quality check and preparation for high-power test of input power couplers for SRF 5-year plan (MEXT-ATD) at KEK by global collaboration for ILC Technology Network (ITN)

Author: Yasuchika Yamamoto[1]

Co-authors: Ashish Kumar [1]; Hiroshi Sakai [1]; Mathieu Omet [1]; Sergey Kazakov [2]; Takafumi Hara [1]; Takeshi Dohmae [1]; Tomohiro Yamada [1]; ryo katayama [1]

[1] *High Energy Accelerator Research Organization*

[2] *Fermi National Accelerator Laboratory*

Corresponding Author: yasuchika.yamamoto@kek.jp

A five-year project (MEXT advanced Accelerator element Technology Development (MEXT-ATD)) funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) began at KEK in FY2023. The goal is to manufacture, construct and test a cryomodule (CM) that satisfies the ILC (International Linear Collider Project) specifications and conduct cooling tests. The MEXT-ATD program is closely related to the ILC Technology Network (ITN). Based on the KEK-DESY license agreement, a 3D model of E-XFEL power coupler was submitted from IJCLAB, and RF simulations of the power coupler were conducted by KEK and FNAL through the US-Japan science and technology cooperation. In KEK, simulations on static/dynamic heat load was also done. From FY2024, production of four sets of input power couplers began (another four sets to be produced in FY2025). At the same time, quality checks were conducted on brazing, TiN coating, and copper plating. The production of four sets of power couplers were completed by the end of Mar/2025. Currently, preparation for high power test at resonant ring system in STF is under progress. In this presentation, the basic specifications and design of the input power coupler as well as the overall manufacturing/test schedule and recent progress will be reported in detailed.

Funding Agency:

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Tuesday Poster Session - Board: TUP63 / **244**

Recent progress of robotic R&D for SRF at KEK

Author: Yasuchika Yamamoto[1]

Co-authors: Hayato Ito [1]; Hiroshi Sakai [1]; Kensei Umemori [1]; Masahiko Hiraki [1]; Takeshi Dohmae [1]; Tomohiro Yamada [1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: yasuchika.yamamoto@kek.jp

Robotic R&D for SRF started from FY2022 at KEK. Some works related to auto-cleaning and assembly in clean room have been done in FY2023. In FY2024, a simulator 'ROBOGUIDE'was introduced, enabling precise orbit development and positioning, moreover, any 3D models developed by CAD became available on ROBOGUIDE. In FY2025, assembly between mock-up cavity and mock-up coupler will be demonstrated, 2D vision system will be also tested, and the effectiveness of clean work performed by robot will be verified through vertical test of SRF cavities. The third task will be collaboratively done between KEK and FNAL through the US-Japan science and technology cooperation. This robotic technology will be used for the on-going five-year project (MEXT advanced Accelerator element Technology Development (MEXT-ATD)) funded by the Ministry of Education, Culture, Sports, Science and Technology (MEXT). The goal is to manufacture, construct and test a cryomodule (CM) that satisfies the ILC (International Linear Collider Project) specifications and conduct cooling tests. The MEXT-ATD program is closely related to the ILC Technology Network (ITN). In this presentation, the recent progress of robotic R&D for SRF at KEK will be reported in detailed.

Funding Agency:

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Tuesday Poster Session - Board: TUP64 / **77**

Field emission and particulate contamination in TRIUMF's superconducting accelerators

Author: Aveen Mahon[1]

Co-author: Thomas Planche [2]

[1] *TRIUMF*

[2] *TRIUMF; University of Victoria*

Corresponding Author: amahon@triumf.ca

Particulate contamination in SRF cavities is known to trigger field emission, a phenomenon where electrons tunnel out from the surface of the cavities due to high electric fields. These rogue electrons limit the achievable accelerating gradient, affecting the final beam energy delivered by the accelerator. The TRIUMF e-Linac and ISAC-II heavy ion accelerators see a progressive onset of field emission in their SRF cavities during operation, despite stringent cleaning and testing procedures prior to installation. One hypothesis is that particulates migrate back into cavities after installation, leading to the renewed onset of field emission. The dynamics of micron scale particulates in vacuum is influenced by their electrostatic charge, and the environment of a particle accelerator is ideal for them to gain such charge. However, fundamental parameters such as composition and charge-to-mass ratio of particulates remain largely unknown. I will present an analysis of particulates collected from TRIUMF accelerators, detailing size, composition and possible sources, and subsequently describe a series of experiments studying the charging and migration mechanisms of particulates in vacuum.

Tuesday Poster Session - Board: TUP65 / **157**

Overview of metal cathode R&D for the CW L-band SRF photoinjector at DESY

Author: Dmitry Bazyl[1]

Co-author: Elmar Vogel [1]

[1] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Author: elmar.vogel@desy.de

Thread-mounted cathode installation directly at the backwall of the gun cavity allows cavity cleaning following cathode installation and thus beneficial for RF performance of the injector. Recent vertical tests of the CW L-band SRF gun cavity with a copper cathode installed demonstrated world-record high axial electric fields (up to 50 MV/m). While beneficial for RF performance, photoemissive performance of copper degrades quickly following air and water exposure (high pressure water rinsing followed by 90 degree bake out). In this work, we provide an overview of metal photocathode R&D activities aimed at addressing a challenging set of requirements with the goal of meeting top-level parameters of the future CW / high-duty-cycle upgrade of the European XFEL: 100 pC at 1 MHz in CW regime.

Funding Agency:

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Tuesday Poster Session - Board: TUP66 / **256**

Commissioning status of the RF power source for the LIPAc SRF linac

Author: Kouki Hirosawa[1]

Co-authors: Francesco Scantamburlo [2]; Ivan Moya [3]; Jean-Pierre Adam [3]; Luis Gonzalez Gallego Sanchez Camacho [4]; Naoya Kubo [1]; Olivier Piquet [5]

[1] *National Institutes for Quantum Science and Technology*

[2] *IFMIF/EVEDA Project Team*

[3] *Fusion for Energy*

[4] *Consorcio IFMIF-DONES España*

[5] *CEA Paris-Saclay*

Corresponding Author: hirosawa.koki@qst.go.jp

The Linear IFMIF Prototype Accelerator (LIPAc) is designed as a high-current deuteron linear accelerator (linac) capable of accelerating a 125-mA beam up to 9 MeV in continuous wave (CW) mode. The RFQ linac and subsequent beam transport lines equipped with several diagnostics successfully commissioned a 119-mA deuteron beam with an 8.75% duty cycle. The superconducting RF (SRF) linac is the remaining critical component to be commissioned in CW to reach the final acceleration target of 9MeV. The installation of the SRF linac into the beamline is currently underway. In preparation for the integrated commissioning of the SRF linac, the RF station has been commissioned in stand-alone mode. Unlike the synchronized RF control of the RFQ (where 8 RF chains inject in one resonant cavity), the SRF-RF control can be fine-tuned individually and new functionalities peculiar to the SRF environment, such as quench detection, have been implemented. This report summarizes the features of the LIPAc SRF-RF system and its current commissioning status.

Tuesday Poster Session - Board: TUP67 / **123**

Implementation of embedded EPICS for MELSEC iQ-R in the SRILAC LLRF System

Author: Akito Uchiyama[1]

Co-authors: Kazunari Yamada [1]; Misaki Komiyama [1]; Nobuhisa Fukunishi [1]

[1] *RIKEN Nishina Center*

Corresponding Author: a-uchi@riken.jp

At the Superconducting RIKEN Linear Accelerator (SRILAC), auxiliary control and monitoring tasks for the RF system, such as RF voltage and power readout, feeder control, and tuner adjustments, are managed using a Mitsubishi MELSEC iQ-R series programmable logic controller (PLC). This PLC is directly connected to the FPGA-based LLRF controller, forming an integrated system for low-level RF operations. In the conventional configuration, the PLC communicated with EPICS via an external Linux computer using the MC protocol over TCP/IP, which often suffered from limited reliability compared with fieldbus-based solutions. To overcome this limitation, we implemented EPICS support directly on the C-language intelligent function module of the iQ-R series. By embedding the IOC in the PLC module itself, the need for an external Linux interface was eliminated, and communication stability was significantly improved. The new system has been deployed and tested in the SRILAC LLRF environment. This paper describes the system architecture, details of the embedded implementation, and operational results obtained during beam operation.

Tuesday Poster Session - Board: TUP68 / **69**

Development of faults identification pipeline for SPIRAL2 LLRF data

Author: Charly Lassalle[1]

Co-authors: Adnan Ghribi [2]; Frédéric Bouly [3]; Marco Di Giacomo [2]; Patrick Bonnay [4]

[1] *Université de Caen Normandie; GANIL*

[2] *GANIL*

[3] *Laboratoire de Physique Subatomique et de Cosmologie*

[4] *Université Grenoble Alpes; CEA Grenoble; Institut de Recherche Interdisciplinaire de Grenoble; Département des Systèmes Basses Températures*

Corresponding Author: charly.lassalle@ganil.fr

SPIRAL2 is a state-of-the-art superconducting linear accelerator for heavy ions, utilizing 26 bulk niobium cavities. The radiofrequency (RF) operation of the SPIRAL2 linac can be disrupted by anomalies that affect its reliability. This work leverages fast, multivariate time-series postmortem data from the Low-Level RF (LLRF) system, processed using a Field-Programmable Gate Array (FPGA), to differentiate anomaly groups. However, interpreting these anomalies traditionally relies on expert analysis, with certain behaviors remaining obscure even to experienced observers.

By adapting the Time2Feat pipeline and applying parameter space reduction techniques such as PCA and t-SNE, this study explores the interpretability of anomalies through intelligent features selection, paving the way for real-time state observers. Clustering performance is benchmarked using DBSCAN, HDBSCAN, K-Means, and OPTICS. A case study on distinguishing hard quenches in postmortem data is highlighted. As a result, a fast and reliable quench detection method is proposed.

Tuesday Poster Session - Board: TUP69 / **178**

Design of an MTCA.4-Based LLRF tuning controller for cryomodules at S3FEL

Author: Jinfu Zhu[1]

Co-authors: Hongli Ding [2]; Zhiyuan Zhang [1]; Jiawei Han [1]; Xiwen Dai [1]; Weiqing Zhang [2]

[1] *Institute of Advanced Science Facilities, Shenzhen*

[2] *Dalian Institute of Chemical Physics*

Corresponding Author: zhujinfu@mail.iasf.ac.cn

This report presents the design of an MTCA.4-based low-level radio frequency (LLRF) tuning controller for the Shenzhen Superconducting Soft X-ray Free Electron Laser (S3FEL). A standard 1.3 GHz cryomodule at S3FEL comprises eight superconducting cavities, each requiring one slow tuner motor control, two fast piezoelectric actuator (PZT) controls, and an additional motor control for high-power coupler antenna depth adjustment. To manage these requirements, two pairs of MTCA.4 control boards (each pair consisting of an AMC and an RTM connected via MTCA Zone3 D1.0 interface) are implemented per cryomodule. The controller's core processing utilizes a Kintex UltraScale KU040 FPGA on the AMC, which acquires cavity detuning data from four cavities through backplane peer-to-peer high-speed communication. An FMC mezzanine card interfacing with the AMC provides eight optically isolated motor control channels. The RTM board delivers eight channels of 16-bit high-precision DAC output for PZT control. Preliminary testing confirms that the developed tuning controller meets the operational requirements for S3FEL's standard superconducting cryomodules.

Tuesday Poster Session - Board: TUP70 / **23**

A low-level radio frequency (LLRF) control system for multiple superconducting cavities based on MicroTCA.4

Author: Wenbin Gao[1]

Co-authors: Nan Gan [1]; Zusheng Zhou [1]; Jiyuan Zhai [1]; Xinpeng Ma [2]

[1] *Institute of High Energy Physics*

[2] *Key Laboratory of Particle Acceleration Physics and Technology*

Corresponding Author: gaowb@ihep.ac.cn

In modern particle accelerators, multiple superconducting cavities are often driven simultaneously by one high-power klystron, thereby reducing the cost of the power supplies. The CEPC TDR specifies 96 cryomodules for 650 MHz 2-cell cavities, with each cryomodule originally housing two cavities. During the horizontal testing phase, however, we plan to simultaneously drive six superconducting cavities per klystron to verify the RF system's reliability. This approach significantly reduces the cost of the power supply but introduces several challenges for high-precision control of superconducting cavities, such as gradient differences due to individual cavity variations, frequency offsets caused by Lorentz force detuning, and the calibration of vector sum of amplitudes and phases for multiple cavities. This paper introduces the design of China's first LLRF control system for multi-superconducting cavity control, based on a fully domestic MicroTCA.4 platform with self-developed hardware and software capable of supporting both pulsed and continuous wave operation modes. Based on the vector-sum control principle, the system utilizes IQ sampling, feedforward-feedback control, and other techniques, eventually achieving high-precision amplitude and phase control and frequency tuning of six superconducting cavities through comprehensive domestic innovation in critical components and control algorithms.

Tuesday Poster Session - Board: TUP71 / **312**

Initial results of the ESS cavities parameters identification at the TS2 towards future LLRF operation

Author: Wojciech Cichalewski[1]

Co-authors: Cecilia Maiano [2]; Kacper Klys [1]; Paolo Pierini [2]

[1] *Lodz University of Technology*

[2] *European Spallation Source*

Corresponding Author: wcichal@dmcs.pl

A dedicated series of tests on the superconducting Medium-Beta and High-Beta cavities has been proposed to determine various parameters critical for future LINAC and LLRF system operation. These studies include measurement of the cavity stiffness coefficient (expressed as the Lorentz Force Detuning factor), evaluation of piezo tuner range and polarity, investigation of piezo capacitance as a function of temperature, and identification of resonator pi-mode frequencies. Additionally, the detection of the main mechanical longitudinal mode and assessment of field regulation performance are also of interest.

This contribution presents the results from several measurement campaigns conducted at the ESS Test Stand 2 (TS2). The development and evaluation of the testing tools, along with the obtained characterization results and plans for future implementation in the ESS LINAC environment, are also discussed.

Funding Agency:

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Tuesday Poster Session - Board: TUP72 / **196**

Progress and challenges on SRF technology development for PERLE

Author: Akira Miyazaki[1]

[1] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

Corresponding Author: akira.miyazaki@cern.ch

Powerful Energy Recovery Linac for Experiments (PERLE) is a compact three-pass ERL project based on SRF technology, being as a new generation machine targeting the 5 MW beam power regime. PERLE will serve as a hub for the validation and exploration of a broad range of accelerator phenomena in an unexplored operational power regime serving for the development of ERL technology for future energy and intensity frontier machines. The SRF cavities have been designed and prototyped to be similar or virtually identically to the ttbar option of FCCee, namely, 800 MHz bulk niobium cavities with Q_0>3×10^10 around 22 MV/m. This ambitious performance will be enabled by state-of-the-art medium temperature baking. In this contribution, we discuss progress and challenges in cavity fabrication, higher order mode couplers and beam line absorbers, and the cryomodule with a special focus on magnetic shield and potential flux expulsion scheme.

Tuesday Poster Session - Board: TUP73 / **345**

Thermoelectric current mitigation for 1.3 GHz Nb-on-Cu cavities

Author: Kristof Brunner[1]

[1] *European Organization for Nuclear Research*

Corresponding Author: kristof.brunner@cern.ch

In the case of Nb-on-Cu, or other coated cavities the thermoelectric currents induced during the cooldown of the cavity may influence the RF performance of the cavity. This effect was observed on several types of cavities in the past (e.g. 1.3 GHz elliptical cavities or HIE-ISOLDE quarter wave resonator). One of the usual methods for reducing the effect of such currents is to slow down the cooldown rate. This does not necessarily mitigate the currents, but thanks to the high thermal conductivity of copper, it usually results in a low thermal gradient across the cavity, thus resulting in lower thermoelectric current. Another way of reducing the thermal gradient, is to control the environment the cavity is in, using a shield of some sort to protect the cavity from direct cooling by the evaporating helium. We show that a very simple copper barrier between the helium being inserted and the cavity, is sufficient in reducing the thermal gradient, increasing reproducibility of the measurements independent of the cooldown speed or other variables. However, as such a design requirement is hardly feasible in a cryomodule, we are also studying the possibility of mitigating the thermoelectric currents by applying an insulating layer between the copper and the niobium. Our first copper-insulator-niobium cavity was tested, and the quality factor showed no sensitivity to the thermal gradient during the cooldown at all. This is a promising result both for Nb-on-Cu cavities, and for other

Tuesday Poster Session - Board: TUP74 / **119**

The RF design of a fast reactive tuner for UK-XFEL superconductor cavities

Author: Hongping Jiang[1]

[1] *Lancaster University*

Corresponding Author: h.jiang6@lancaster.ac.uk

A Ferro Electric Fast Reactive Tuner(FE-FRT) for UK-XFEL superconducting Tesla Cavities is under development, which is used to suppress the microphonics of the superconducting cavities, a fast dynamic detuning. The EF-FRT tuner doesn't have moving parts and so has an extremely fast tuning process to compensate the microphonics. The RF design of the FRT includes the optimization of the Figure of Merit by changing the geometry of the tuner using the CST eigenmode solver. With a higher FoM that means there is a larger tuning range with fixed power dissipated in the FE-FRT. An overview of the approximation calculation theory and automatic optimization of FoM will be discussed in detail.

Tuesday Poster Session - Board: TUP75 / **300**

Damping microphonics in SRF cavities using boron nitride nanotubes

Author: Kevin Jordan[1]

Co-authors: George Biallas [2]; Lyndsey Scammell [3]; Matt Weaks [1]; Peter Owen [1]; Tom Powers [1]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Hyperboloid LLC*

[3] *BNNT LLC*

Corresponding Author: jordan@jlab.org

The design of the ten additional CEBAF Upgrade Cryomodules leads to significantly higher fault rates than the 40 original cryomodules, due to sensitivity to microphonics. Cartridges that compress pellets of boron nitride nanotubes (BNNT) are mounted in parallel to the SRF cavities of two refurbished Upgrade Cryomodules. Now substituted into CEBAF, these cryomodules exhibit significant microphonics reduction such that their fault rates are the lowest of all cryomodules in CEBAF. The boron nitride nanotube pellets are developed and manufactured by BNNT LLC of Newport News, Virginia and the cartridge design, testing and installation was sponsored by a Small Business Innovative Research Grant from the US DOE Office of Science, Office of Nuclear Research. The cartridge design, its testing in a two-SRF cavity, Horizontal Test Bed, the details of incorporation into the CEBAF Upgrade Cryomodule and operational data are presented.

Funding Agency:

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Tuesday Poster Session - Board: TUP76 / **301**

Results from a helium flowmeter that measures SRF cavity Q0s In situ

Author: Dakota Christian[1]

Co-authors: Claire Jones [1]; Gary Croke [1]; George Biallas [2]; Jerone Samari [1]; Kevin Jordan [1]; Michael McCaughan [1]; Michael Tiefenback [1]; Peter Owen [1]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Hyperboloid LLC*

Corresponding Author: jordan@jlab.org

We report on the easily accomplished, in situ measurement of individual SRF Cavity dissipation in CEBAF cryomodules at the Thomas Jefferson National Accelerator Facility (JLab). Calculated Q0s from the data allows assessing the health of cryomodules over time. A 2022 SBIR Grant from the Office of Nuclear Physics, DOE Office of Science, to Hyperboloid LLC enabled development. JLab provided the test bed environment and development of electronics through a cooperative agreement. Use of the flowmeter for determining the Q0s of LCLS-II-HE cryomodules built at JLab as well as results from other installations are also reported. The meter measures the helium vapor evaporating from the 2 K helium bath at 1/30 atm, resolving 0.05 g/s = 1 W. As a power meter, it has a broad range, measuring from 10 W to 200 W. The meter's sensitivity uses voltage signal change when the superconductor (SC) sensor (Tc = 9.2 K) changes to normal conducing. Cooling from helium vapor is bucked against resistive heat from an adjacent resistive wire until the sensor's temperature is non-SC. An electronics chassis interfaced to an AtoD/DtoA LabJack T7 couples to Linux-based EPICS, providing control and data processing of the signals. The Hyperboloid flowmeter is now a commercial instrument, available to the SRF community.

Funding Agency:

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Tuesday Poster Session - Board: TUP77 / **313**

Nb3Sn thin films for dark matter detection

Author: Andre Juliao[1]

Co-authors: Lance Cooley [1]; Nikolya Cadavid [2]; Gianpaolo Carosi [3]

[1] *National High Magnetic Field Laboratory*

[2] *Florida State University*

[3] *Lawrence Livermore National Laboratory*

Corresponding Author: arj14c@fsu.edu

Nb3Sn has great potential to be the next generation superconducting material on the inside of Cu superconducting radiofrequency cavities (SRF) due to its relatively high critical temperature Tc ≈ 18 K compared to other low temperature superconductors e.g., Nb with Tc ≈ 9 K. For Axion detection, cavities might operate below 100 mK, and copper bodies are preferred. Here, we report methods to make Nb3Sn films on copper substrates that could be scaled to microwave detectors. We develop bronze routes to facilitate a Nb-Sn reaction at ~700 ℃, well below the melting point of Cu. We use Ta as a diffusion barrier and possible mitigation of thermal contraction mismatch. High Sn activity is obtained by using Cu25at.%Sn (epsilon phase) instead of alpha-bronze as our Sn source. We then explored formation of Nb3Sn via reaction of the multilayer Cu substrate/barrier/Nb/bronze at >700 ℃. Cross-sectional SEM/FIB analyses were performed to see the differences in morphology and composition of the films. Since copper was the dominant material, thermal contraction applied stress to the resulting Nb3Sn films reducing Tc to ~15 K. We also designed, modeled, and machined a cavity to test the RF properties of our thin films.

Funding Agency:

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Tuesday Poster Session - Board: TUP78 / **67**

Coming closer to high frequency gravitational waves detection with MAGO

Author: Giovanni Marconato[1]

Co-authors: Alex Melnychuk [2]; Alex Netepenko [2]; Andrea Muhs [3]; Anna Grassellino [2]; Bianca Giaccone [2]; Gudrid Moortgat-Pick [4]; Ivan Gonin [2]; Julien Branlard [3]; Krisztian Peters [3]; Lars Fischer [4]; Lukasz Butkowski [3]; Marc Wenskat [5]; Martin Hierholzer [3]; Matthias Hoffmann [3]; Mona Eberenz [3]; Oleg Pronitchev [2]; Sam Posen [2]; Timergali Khabiboulline [2]; Tom Krokotsch [4]; Vijay Chouhan [2]; Wolfgang Hillert [4]; Yuriy Orlov [2]

[1] *Università degli Studi di Padova*

[2] *Fermi National Accelerator Laboratory*

[3] *Deutsches Elektronen-Synchrotron DESY*

[4] *Universität Hamburg*

[5] *Deutsches Elektronen-Synchrotron DESY; Universität Hamburg*

Corresponding Author: giovanni.marconato@desy.de

In the last years, low frequency gravitational waves (GWs) have been consistently measured by the LIGO-Virgo collaboration, but little to no attention has been paid to higher frequencies GWs in the range of 10 kHz to 100 MHz, at which confirmation for current theories or even new physics could be hidden. The MAGO 2.0 project aims at filling this gap in the parameters space using superconducting radio-frequency (SRF) cavities. Exploiting the excellent Q-factors of these resonators, we plan to detect tiny harmonic deformations induced by GWs which change the boundary conditions of the oscillating electromagnetic field. We present the results of the first cold tests ran at DESY and FNAL using the cavity prototype built 20 years ago at the end of the MAGO collaboration, characterizing the RF spectrum, Q-factor and surface resistance. In particular we present the mechanical vibration spectrum characterization and the RF response of the cavity with the injection of a "fake GW"signal using piezoelectric actuators.

Tuesday Poster Session - Board: TUP79 / **193**

Photon frequency conversion in high-Q superconducting resonators: axion electrodynamics, QED, and nonlinear meissner radiation

Author: Hikaru Ueki[1]

Co-author: James Sauls [1]

[1] *Louisiana State University*

Corresponding Author: uekih@lsu.edu

Bogorad et al. proposed Superconducting Radio-Frequency (SRF) cavities with high quality factors as a platform for detecting axions, which are a dark matter candidate, as well as low-energy QED

corrections that give rise to photon-photon scattering [1]. The idea is to use the cubic nonlinearity of axion-electrodynamics to detect the axion field by measuring photons at a signal frequency ω3 = 2 ω1 - ω2 in an SRF cavity simultaneously pumped with photons at two resonant frequencies ω1 and ω2. Signal photons are sourced by axion-mediated currents, or by virtual electron-positron pairs in the vacuum of the cavity [1,2]. However, the Meissner screening current is a nonlinear function (nonlinear Meissner effect [NLM]) of the field at the surface, and thus sources photons at the signal frequency ω3 [3]. We report calculations of the number of NLM photons, leakage noise photons, and the resulting impact on the sensitivity of SRF cavities to axion and QED mediated photon conversion [4]. For SRF cavities with ultra-high-Q we show that the NLM effect parametrically shifts the frequency of surface generated photons sufficiently away from the signal frequency to allow for detection of nonlinear QED frequency conversion. We also show that dual-cavity setup for source and detector [5] and the single-cavity setup proposed for heterodyne detection of galactic axion dark matter [6] can suppress the NLM and leakage backgrounds.

Footnotes:

[1] Z. Bogorad et al., Phys. Rev. Lett. 123, 021801 (2019).
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Funding Agency:

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Tuesday Poster Session - Board: TUP80 / **213**

Search for dark matter with superconducting cavities and qubits

Author: Tatsumi Nitta[1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: tatsumi@post.kek.jp

Dark matter with masses much less than 1 eV/c² is treated as a classical field, commonly referred to as wavelike dark matter. Among the leading candidates is the axion, which may have a mass on the order of μeV and can be converted into ordinary microwave photons of minuscule amplitude under a strong magnetic field. Leading wavelike dark matter searches often employ SRF cavities as detectors for enhancing tiny signals. Therefore, the sensitivity of detection is proportion to the quality factor of the cavity.

Our research explores a broad range of cavity-based technologies for particle physics applications. For example, we aim to realize high-Q superconducting cavities at the single-photon regime at millikelvin temperatures to maximize sensitivity in dark matter detection. We also investigate the development of SRF cavities with high magnetic-field tolerance for axion searches. Additionally, we couple cavities to superconducting qubits to assess their potential for versatile quantum sensing technologies, such as single-photon counting or direct excitation of transmon qubits.

In this poster, we present our approach to dark matter detection using SRF cavities and report on the progress of each application.

Tuesday Poster Session - Board: TUP81 / **325**

Current status of the high current 1.5 GHz SRF cavity prototypes for VSR Demo

Author: Adolfo Velez[1]

Co-authors: Andranik Tsakanian [2]; Felix Glöckner [2]; Hans Walter Glock [2]; Jens Knobloch [3]

[1] *TU Dortmund University*

[2] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[3] *University of Siegen*

Corresponding Author: adolfo.velez@helmholtz-berlin.de

The BESSY Variable pulse-length Storage Ring (VSR) Demo project aimed to provide short and long pulses simultaneously in the BESSY II storage Ring. To achieve this goal HZB has developed high current Continuous Wave (CW) Superconducting Radio Frequency (SRF) cavities operating at 1.5 GHz for 300 mA beams with large damping capabilities to cope with the HOM powers expected. This paper presents the current status, fabrication and lessons learned as results from the delivered prototype by Reseach Instruments and tests carried on at SupraLab HZB.

Tuesday Poster Session - Board: TUP82 / **319**

591 MHz SRF cavity for EIC ESR

Author: Wencan Xu[1]

Co-authors: Alex Zaltsman [1]; Jesse Fite [1]; Jiquan Guo [2]; Robert Rimmer [2]; Silvia Verdu-Andres [1]; Zachary Conway [2]

[1] *Brookhaven National Laboratory*

[2] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: wxu@bnl.gov

Electron-Ion Collider (EIC) is a next generation particle accelerator to be built at Brookhaven National Laboratory, in partnership with Thomas Jefferson National Accelerator Facility. In Electron Storage Ring (ESR), 18 single-cell 591 MHz SRF cavities are required to compensate for energy loss from synchronic radiation. Effective damping of higher-order-modes (HOMs) is also critical to ensure beam stability. This paper presents the design of the single-cell 591 MHz cavity, including cavity geometry optimization, multipacting evaluation, HOM damping analysis.

Funding Agency:

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Tuesday Poster Session - Board: TUP83 / **321**

High power FPC progress for EIC ESR SRF cavities

Author: Wencan Xu[1]

Co-authors: Jesse Fite [1]; Silvia Verdu-Andres [1]; Zachary Conway [2]

[1] *Brookhaven National Laboratory*

[2] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: wxu@bnl.gov

In EIC Electron Storage Ring (ESR), 18 single-cell 591 MHz SRF cavities are required to compensate for up to 10 MW energy loss from synchronic radiation. There are two FPCs to deliver 800 kW RF power to each cavity. The FPC was design and under prototyping. This paper presents the FPC design and manufacture progress of FPC.

Funding Agency:

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Hot Topic Session: **2** - Board: HT2 / **316**

Hot Topic 2: development toward extremely high performance superconducting cavities

Author: Akira Miyazaki[1]

[1] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

Corresponding Author: akira.miyazaki@cern.ch

For the sustainable accelerators in the future, we need to develop extremely high performance superconducting cavities. This would require collaboration between physicists and engineers towards the same goal. In this hot topic, the internationally distinguished panel members and the audience will discuss state-of-the-art of superconducting cavities and overview the perspective of research directions beyond the state-of-the-art. The session will be coordinated by a few provocative questions on the screen and then will trigger exciting debate among the participants.

Wednesday Oral Session: **A** - Board: WEA01 / **100**

RF characterization of 1.3 GHz single-cell Nb/Cu full-seamless cavity manufactured by hydroforming

Author: Hayato Araki[1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: arakih@post.kek.jp

The Future Circular Collider (FCC) will employ 400 MHz elliptical cavities with niobium coating on copper substrates. Since the performance requirements of the FCC are higher than those of the Large Hadron Collider, which has similar operating conditions, a “seamless”substrate without welding seams is being investigated to achieve these requirements. Hydroforming is one of the methods

to fabricate seamless-cavities for mass production, and the first prototype series of 1.3 GHz single-cell cavities for R&D was completed in 2023 through a collaboration between CERN and KEK. The cavities were hydroformed by KEK, niobium thin film was coated on them by CERN with HiPIMS, and their performance was measured by both KEK and CERN. Although the surface resistance was not small enough in high field, the target accelerating gradient 12 MV/m was achieved.

Funding Agency:

Amada Foundation

Wednesday Oral Session: **A** - Board: WEA02 / **24**

Nb3Sn superconducting cavity developments for heavy-ion beams

Author: Troy Petersen[1]

[1] *Argonne National Laboratory*

Corresponding Author: tpetersen@anl.gov

Niobium-tin has been identified as the most promising next-generation superconducting material for accelerator cavities. This is due to the higher critical temperature (Tc = 18 K) of Nb3Sn compared to niobium (TC = 9.2 K), which leads to greatly reduced RF losses in the cavity during 4.5 K operation. This allows two important changes during cavity and cryomodule design. First, the higher Tc leads to negligible BCS losses when operated at 4.5 K, which allows for a higher frequency to be used, translating to significantly smaller cavities and cryomodules. Second, the reduced dissipated power lowers the required cryogenic cooling capacity, meaning that cavities can feasibly be operated on 5-10 W cryocoolers instead of a centralized helium refrigeration plant. These plants and distribution systems are costly and complex, requiring skilled technicians for operation and maintenance. These fundamental changes present an opportunity for a paradigm shift in how low-beta linacs are designed and operated. Fabrication and testing results of first prototypes are discussed.

Wednesday Oral Session: **A** - Board: WEA03 / **70**

Towards high power tests of an FE-FRT for transient detuning

Author: Samuel Smith[1]

Co-authors: Alick Macpherson [1]; Ilan Ben-Zvi [2]; Jeremy Bastard [1]; Niall Stapley [1]; Paul Schneider [1]

[1] *European Organization for Nuclear Research*

[2] *Stony Brook University*

Corresponding Author: samuel.jack.smith@cern.ch

The design, fabrication, and validation progress towards a ferroelectric fast reactive tuner (FE-FRT) as a demonstrator of a high-power tuner for beam loading compensation at LHC injection settings is presented. Such compensation is referred to as transient detuning compensation and involves discrete frequency switching of an LHC cavity configuration on sub-microsecond time scales. The FE-FRT is operated in a two-state mode with a 7 kV bias applied across a BaTiO3/SrTiO3-Mg ferroelectric material in the tuner stub to provide the required cavity frequency shift. To achieve this, the device has been designed to operate as a coupled resonant tuner that provides an ~8 kHz cavity

tuning range. As an FE-FRT design, the tuner must tolerate a reactive power load of ±226 kW and ~3 kW of dissipated power. The key design decisions taken are presented, along with the specific optimisation of the tuner in terms of the expected performance. Finally, measurements and first results for the tuner demonstrator validation process are discussed.

Wednesday Oral Session: A - Board: WEA04 / **62**

First beam acceleration using cryo-cooled Nb3Sn coated cavity at IMP

Author: Ziqin Yang[1]

Co-authors: Yuan He [2]; Zhijun Wang [2]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Institute of Modern Physics*

Corresponding Author: yzq@impcas.ac.cn

Operational experience of the LHe-Free (LHe-free) Nb3Sn demo SRF electron linac over the past year will be reported. A statistical analysis was conducted on beam loss-induced irradiation effects on the Nb3Sn thin film of the superconducting cavity inner surfaces, with subsequent assessment of their impact. An irradiation terminal facility was constructed to conduct experiments on electron beam irradiation for wastewater treatment. A 650 MHz 5-cell Nb3Sn cavity coated by the tin vapor diffusion method has been vertically tested to verify its RF performance.

Funding Agency:

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Wednesday Oral Session: A - Board: WEA05 / **29**

Beam acceleration with a Nb3Sn cryomodule at JLAB

Author: Rong-Li Geng[1]

[1] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: geng@jlab.org

A CEBAF-style quarter cryomodule with two Nb3Sn coated 5-cell CEBAF-style SRF cavities was tested successfully in the cryomodule test facility (CMTF) at JLab in 2024. Efforts continued since then toward a beam test of that cryomodule in the upgraded injector test facility (UITF) at JLab. In this talk, we will report on the beam test results and the planned future steps in further developing the Nb3Sn cryomodule technology in support of CEBAF accelerator upgrade scenarios and other application beyond nuclear physics.

Funding Agency:

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Wednesday Oral Session: A - Board: WEA06 / **78**

Performance of the Cornell conduction-cooled Nb3Sn cavity cryomodule

Author: Jake Parsons[1]

Co-authors: Adam Holic [1]; Greg Kulina [1]; Holly Conklin [1]; James Sears [1]; Jessica Turco [1]; Matthias Liepe [1]; Peter Quigley [1]; Terri Gruber-Hine [1]; Valery Shemelin [1]

[1] *Cornell University*

Corresponding Author: jrp356@cornell.edu

Recent improvements in Nb3Sn cavity and commercial cryocooler performance have made the fabrication of conduction-cooled cryomodules for SRF cavities feasible, which drastically expands SRF applications to medical imaging, water purification, and security. Cornell has developed a turn-key, conduction-cooled cryomodule to operate a 1.3 GHz Nb3Sn SRF cavity by optimizing the cooling output of two commercial cryocoolers. The cryomodule, cavity, and RF input coupler have been designed for very high CW beam current operation (>100 mA) and high RF power (100 –200 kW CW RF). We present the design, optimization, and assembly process of this conduction-cooled cryomodule as well as performance during initial cooldown tests and low power RF testing.

Wednesday Oral Session: B - Board: WEB01 / **14**

Insights on the effect of N and O impurities towards optimizing SRF cavity performance

Author: Hannah Hu[1]

Co-authors: Daniel Bafia [2]; Young-Kee Kim [1]

[1] *University of Chicago*

[2] *Fermi National Accelerator Laboratory*

Corresponding Author: hannahhu@uchicago.edu

Recent developments in the high Q and high gradient frontier of SRF cavities have focused on altering the surface impurity profile through *in-situ* baking, furnace baking, and doping to introduce and diffuse impurities such as O, N and C. However, the precise role of each impurity in improving performance is not fully understood. We take a materials-focused approach to identifying the efficiency of O and N impurities. Niobium cavity cutouts are baked at temperatures from 120-800°C with and without nitrogen injection as well as subjected to varying amounts of EP removal. Time-of-flight secondary ion mass spectrometry is used to quantify the absolute concentration of each impurity, and these material studies are correlated to the BCS surface resistance measured through cavity tests. These results are compared with BCS theory as well as with first principle calculations. We find that the same reduction in BCS resistance can be realized with either O or N. Furthermore, the concentration of N required is ten times less than that of O to achieve the same improvement in performance.

Wednesday Oral Session: B - Board: WEB02 / **45**

Flux ratcheting: enhanced magnetic flux expulsion in SIS multilayer structures

Author: Daniel Turner[1]

Co-authors: Alick Macpherson [1]; Isabel González Díaz-Palacio [2]; Lea Preece [2]; Marc Wenskat [2]

[1] *European Organization for Nuclear Research*

[2] *Universität Hamburg*

Corresponding Author: daniel.andrew.turner@cern.ch

A program of quantitative measurements of magnetic flux expulsion on flat macroscopic samples has been used to assess and categorise magnetic expulsion efficiency. The measurement setup is a magnetic flux lens based on closed-topological heating/cooling through the material's superconducting transition. This offers systematic and repeatable expulsion measurements for bulk, thin film and multilayer samples. Of particular interest is the magnetic response of superconductor-insulator-superconductor (SIS) multilayer structures, which can exhibit a response that is characteristically different to that of bulk Niobium, if thermally manipulated in a specific way - this process we term "flux ratcheting".

Flux ratcheting is the incremental expulsion of trapped magnetic flux with repeated, controlled thermal cycles on a SIS sample, such that the trapped flux is incrementally moved ("ratcheted") out, with limited magnetic relaxation. Measurements indicate flux ratcheting is particular to the SIS structure, and requires the Tc of the surface thin film to be greater than that of the substrate.

To assess the impact of flux ratcheting on cavity performance, the application of an SIS structure to a 1.3 GHz bulk Nb cavity has been prepared, and referenced to the baseline performance of the bare Nb cavity. The RF performance with and without flux ratcheting is compared, and first implications of magnetic flux ratcheting to RF cavity performance are discussed.

Wednesday Oral Session: B - Board: WEB03 / **5**

Oxygen vacancies in niobium pentoxide as a source of two-level system losses in superconducting niobium

Author: Daniel Bafia[1]

Co-authors: Akshay Murthy [1]; Alexander Romanenko [1]; Anna Grassellino [1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: dbafia@fnal.gov

Two-level systems (TLS) have long been a catch-all explanation for RF loss and quantum decoherence in superconducting devices. In our study, the first to directly link TLS losses to a specific physical mechanism, we demonstrate that oxygen vacancies in the naturally formed Nb_2O_5 on oxidized niobium are a major driver of such dissipation. We performed sequential in situ vacuum-baking treatments on niobium superconducting radio-frequency (SRF) cavities and used time-of-flight secondary ion mass spectrometry (TOF-SIMS) to reveal a nonmonotonic evolution in cavity quality factor (Q_0). This behavior correlates with the interplay of Nb_2O_5 vacancy generation and oxide-thickness dissolution. We localize this effect to the oxide itself and present the insignificant role of diffused interstitial oxygen in the underlying Nb by regrowing the oxide via wet oxidation, revealing a mitigation of aggravated TLS losses. We hypothesize that such vacancies in the pentoxide serve as magnetic impurities and are a source of TLS-driven rf loss. Although our measurements center on 3-D SRF cavities, the insights gained here have significant implications for mitigating decoherence in 2-D superconducting qubits.

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Wednesday Oral Session: B - Board: WEB04 / **51**

Direct measurement of magnetic fields generated in Nb3Sn samples during cooldown

Author: Felix Kramer[1]

Co-authors: Jens Knobloch [2]; Oliver Kugeler [1]

[1] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[2] *Helmholtz-Zentrum Berlin für Materialien und Energie; University of Siegen*

Corresponding Author: f.kramer@helmholtz-berlin.de

We present trapped flux data of Nb3Sn samples prepared with sputtering and via bronze route. The data shows that during cooldown magnetic fields with magnitudes several times that of the earth's magnetic field can be generated. As the sample becomes superconducting the fields are trapped and can be directly measured by our setup. In the data a correlation between field magnitude and the temperature gradient during cooldown is evident, where higher gradients lead to more generated magnetic field. These results can have an important impact on the production and operation of Nb3Sn cavities.

Wednesday Oral Session: B - Board: WEB05 / **61**

Measurements of RF magnetic field limits of Nb and Nb3Sn

Author: Nicole Verboncoeur[1]

Co-authors: Adam Holic [2]; James Sears [2]; Liana Shpani [2]; Matthias Liepe [2]; Ryan Porter [3]; Thomas Oseroff [2]

[1] *Cornell University (CLASSE)*

[2] *Cornell University*

[3] *SLAC National Accelerator Laboratory*

Corresponding Author: nmv39@cornell.edu

Measuring fundamental RF field limits of candidate superconductors for SRF cavities is challenging as local defects and thermal heating can lead to premature quench at field well below the ultimate limit of a superconducting material. Cornell has developed, fabricated, and commissioned a unique sample host cavity that allows for exposing superconducting material samples to very high RF fields (>0.5 T) in very short RF pulse operation. Using high pulsed RF power, these high field are reached at the sample within a few microseconds. This very short pulse operation diminishes the effects of localized defects and thermal heating, thereby allows exploring fundamental field limits as function of temperature. In this talk we will present details form the design and commissioning of this system. We will show detailed measurement results of the (fundamental) RF field limit vs T for electropolished niobium and for Nb3Sn. For Nb, our results demonstrate that the high-field Q slope induced quench observed in SRF cavities is not fundamental but a result of thermal instability; the material itself is cable of supporting fields well above 200 mT, in agreement with the predicted superheating field of clean niobium.

Wednesday Oral Session: B - Board: WEB06C / **90**

Dynamics of few-trapped vortices in niobium at microwave frequencies

Author: Chung-Yang Wang[1]

Co-author: Steven Anlage [1]

[1] *University of Maryland, College Park*

Corresponding Author: anlage@umd.edu

Trapped vortices in superconductors introduce residual resistance in superconducting radio-frequency (SRF) cavities and disrupt the operation of superconducting quantum and digital electronic circuits. Understanding the detailed dynamics of trapped vortices under oscillating magnetic fields is essential for advancing these technologies. We have developed a near-field magnetic microwave microscope to study the dynamics of a limited number of trapped vortices under the probe when stimulated by a localized rf magnetic field.† By measuring the local second-harmonic response (P_2f) at sub-femto-Watt levels, we isolate signals exclusively arising from trapped vortices, excluding contributions from surface defects and Meissner screening currents. Toy models of Niobium superconductor hosting vortex pinning sites are introduced and studied with Time-Dependent Ginzburg-Landau (TDGL) simulations‡ of probe/sample interaction to better understand the measured second-harmonic response. The simulation results demonstrate that the second-harmonic response of trapped vortex motion under a localized rf magnetic field shares key features with the experimental data. This measurement technique provides access to vortex dynamics at the micron scale, such as depinning events and spatially-resolved pinning properties, as demonstrated in measurements on a Niobium film with an antidot flux pinning array.

Footnotes:

† C.-Y. Wang, S. M. Anlage, "Microwave Microscope Studies of Trapped Vortex Dynamics in Superconductors,"https://arxiv.org/abs/2503.02811.
‡ B. Oripov, S. M. Anlage, Phys. Rev. E 101, 033306 (2020).

Funding Agency:

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Wednesday Oral Session: B - Board: WEB07C / **71**

Effects of thin gold layers on performance of 2.6 GHz SRF cavity

Author: Sadie Seddon-Stettler[1]

Co-authors: Cristobal Mendez [2]; Matthias Liepe [2]; Nathan Sitaraman [2]; Steven Sibener [3]; Thomas Oseroff [2]; Tomás Arias [2]; Van Do [3]

[1] *Cornell University (CLASSE)*

[2] *Cornell University*

[3] *University of Chicago*

Corresponding Author: sgs238@cornell.edu

SRF cavities are a critical technology both for particle accelerators, where they enable high energies and efficient operation, and superconducting quantum circuits, where they enable large coherence times for qubits. In both applications, the need for better performing cavities with higher quality factors is clear. The native oxide that forms on the surface of niobium may be the source of conductive losses in high-energy accelerator applications and of two level system losses in low-energy quantum applications. Previous work from Cornell University studied the effect of passivating the niobium oxide on an RF sample plate with a thin layer of gold, selected for its properties as a non-oxidizing normal conductor. At sub-nanometer thicknesses, the sample showed an increased quality factor. In this paper, we report first RF results scaling up the treatment for full-scale cavity testing using electrochemical deposition of gold on a 2.6 GHz niobium SRF cavity. We also report sample imaging characterizing the growth of thin gold films on niobium, and DFT calculations on the effect of gold on the presence of oxygen impurities in niobium.

Funding Agency:

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Thursday Oral Session: A - Board: THA01 / **19**

Production of Nb3Sn film on copper substrate by the bronze route and the RF characterization of samples with the quadrupole resonator

Author: Ming Lu[1]

Co-authors: Sebastian Keckert [2]; Felix Kramer [2]; Aleksandr Zubtsovskii [3]; Alena Prudnikava [2]; Jens Knobloch [3]; Oliver Kugeler [2]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[3] *University of Siegen*

Corresponding Author: luming@impcas.ac.cn

Copper-based Nb3Sn cavity is a promising candidate for next generation accelerator applications in the field of superconducting radio frequency (SRF). It combines the excellent thermal conductivity of copper and the superior superconducting properties of Nb3Sn, and has the potential to greatly improve the performance of the SRF cavity. The electrochemical and thermal synthesis (ETS) bronze route is one of the proven methods to achieve Nb3Sn coating on copper. Its advantages are low cost, simple operation, suitable for complex cavity types and mass production. In this report, we have prepared a copper-based Nb3Sn sample specifically for Quadrupole Resonator (QPR) testing. We provide a complete set of QPR sample preparation processes from copper electropolishing, Nb sputtering, electrodeposition and heat treatment to synthesize Nb3Sn. By optimizing the entire preparation process and key parameters, a new Cu-based Nb3Sn QPR sample was successfully prepared and its RF properties have been characterized by QPR testing system at HZB.

Thursday Oral Session: A - Board: THA02 / **12**

Development of Nb3Sn coatings on copper at INFN-LNL

Author: Dorothea Fonnesu[1]

Co-authors: Aleksandr Zubtsovskii [2]; Cristian Pira [1]; Davide Ford [3]; Eduard Chyhyrynets [1]; Felix Kramer [4]; Giovanni Marconato [5]; Jens Knobloch [2]; Marc Wenskat [6]; Matteo Lazzari [3]; Oliver Kugeler [4]; Sebastian Keckert [4]; Thomas Proslier [7]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *University of Siegen*

[3] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro*

[4] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[5] *Università degli Studi di Padova*

[6] *Universität Hamburg*

[7] *Université Paris-Saclay*

Corresponding Author: fonnesu@infn.it

The successful development of Nb3Sn/Cu coatings for the SRF cavities of next generation particle accelerators would result in the reduction of the needed cryogenic power by a factor 3 with respect to what normally needed for bulk Nb cavities, while maintaining operation at 4.5 K. In the framework of the I.FAST and ISAS collaborations, research activities are carried out at INFN-LNL to develop new technologies for the application of Nb3Sn on Cu, including seamless spinning of cavity prototypes, surface chemical preparation, cavity coating and testing. At the same time, an optimized recipe for Nb3Sn films deposited via DCMS has been established on small samples and is discussed in this work. The recipe delivers films showing a Tc ≈ 17 K, at deposition temperatures ≤ 650 °C, on a Cu substrate pre-coated with a 30-micron thick buffer layer of Nb. The deposition recipe is validated on bulk Nb by measuring the RF properties on a QPR sample, with the results being also discussed in this work. A surface resistance of 23 nΩ at 4.5 K (at 20 mT, 417 MHz, with quench field ~ 70 mT) is measured, which is about 5 times larger than the baseline specifications for the LHC Nb/Cu cavities and already fulfills the requirements for the FCC-ee. Finally, the expected challenges toward the scalability of the coating recipe to an elliptical cavity prototype, and the perspectives for further recipe refinement are discussed.

Funding Agency:

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Thursday Oral Session: A - Board: THA03 / **80**

Improving quench fields of enhanced-Tc surfaces

Author: Nathan Sitaraman[1]

Co-authors: Nicole Verboncoeur [1]; Thomas Oseroff [1]; Matthias Liepe [1]; Ryan Porter [2]

[1] *Cornell University*

[2] *SLAC National Accelerator Laboratory*

Corresponding Author: nss87@cornell.edu

The sensitivity of compound superconductors to gradient-limiting defects is well established. To overcome this challenge and develop recipes for enhanced-Tc surfaces that approach their fundamental limits, we take a multi-pronged theoretical approach: we identify material systems where low-Tc or normal-conducting defects are less likely to occur, where bulk superconducting properties favor proximity coupling of defects, and where clean interfaces with the niobium substrate allow for thinner films and better thermal stability. We present progress toward growing ultra-thin-film Nb-Zr and Nb3Al superconductors on niobium with the goal of achieving high quality factors at unprecedented fields.

Funding Agency:

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Thursday Oral Session: A - Board: THA04 / **25**

Studies as a function of different ALD capping layers on cavity losses for QIS and accelerators

Author: Laura Grassellino[1]

Co-authors: Akshay Murthy [1]; Alexander Romanenko [1]; Anna Grassellino [1]; Daniel Bafia [1]; Grigory Eremeev [1]; Sam Posen [1]; Sergey Belomestnykh [1]; Thomas Proslier [2]; Yasmine Kalboussi [3]

[1] *Fermi National Accelerator Laboratory*

[2] *Université Paris-Saclay*

[3] *Commissariat à l'Energie Atomique*

Corresponding Author: laurag@fnal.gov

Niobium-based bulk SRF cavities have demonstrated exceptional performance. To further improve niobium cavity performance, we present studies involving a novel surface engineering process designed to prevent the formation of amorphous niobium oxides on the surface. This is achieved by encapsulating the niobium surface using thermal Atomic-Layer-Deposition (ALD). This technique has been shown to enhance the properties of niobium cavities and 2D resonators. This study not only aims to improve SRF performance at high fields but also has the potential to enhance the quality factor in low-field regimes, particularly for quantum applications. For the method to be effective, it is essential to have a clean interface between the encapsulating layer and the bulk niobium. Achieving this requires a uniform coating across the entire cavity surface and efficient removal of the underlying niobium oxides. To optimize the process, a variety of material characterization tools have been utilized to refine parameters such as thin film thickness and annealing conditions. Cavity RF measurements were performed at the vertical test facilities at FNAL to assess the Q vs. Eacc curves for accelerator applications, as well as at the SQMS dilution refrigerators to investigate the full two-level system (TLS) losses at milliKelvin and single-photon levels. Based on the results, we characterized the loss of different oxides in various regimes and applications, comparing them to natural niobium pentoxide.

Funding Agency:

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Thursday Oral Session: A - Board: THA05 / **20**

Understanding anti-Q-slope and Q-slope in SRF cavities: a unified theoretical framework

Author: Antonio Bianchi[1]

[1] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: antonio.bianchi@mi.infn.it

In the SRF community, the origin of the anti-Q-slope in bulk niobium cavities and the Q-slope in niobium-coated copper cavities remains an open question. In this contribution, we propose a theoretical framework explaining both phenomena through a unified approach. The distribution function of quasiparticles may play a crucial role in the response of a superconductor exposed to radio-frequency (RF) fields. In SRF applications, the non-equilibrium dynamics of quasiparticles is traditionally considered independently of phonon dynamics. However, under certain conditions, quasiparticle-phonon scattering in niobium could dominate the dynamic process, making phonon decoupling unfeasible. Unlike previous models, our approach considers the dynamics of quasiparticles and phonons together. For bulk niobium with doped impurities, we show that the non-equilibrium quasiparticle distribution deviates significantly from the Fermi-Dirac distribution and effectively reduces the surface resistance. In niobium-coated cavities, the niobium/copper interface increases the phonon density near the RF surface, leading to a reduction of the order parameter and an increase in surface resistance. In this contribution, we present calculations of the coupled kinetic equations describing the non-equilibrium distributions of quasiparticles and phonons under RF fields and compare our theoretical predictions with experimental data, offering new insights into the optimization of SRF cavity performance.

Thursday Oral Session: A - Board: THA06 / **17**

Nonequilibrium corrections and Higgs mode in superconducting devices: unraveling the pronounced Anti-Q slope in high-frequency regime and current-dependent kinetic inductance

Author: Takayuki Kubo[1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: kubotaka@post.kek.jp

The anti-Q-slope observed in superconducting RF (SRF) cavities has been a longstanding puzzle. Previous studies by Gurevich [1] and Kubo-Gurevich [2] linked this phenomenon to the smearing of the density of states under high RF current. However, the experimentally observed trend of a more pronounced anti-Q-slope with increasing frequency remains unexplained. Recent theoretical investigations using the Keldysh formalism of nonequilibrium superconductivity have provided new insights [3,4]. They revealed that in superconductors exposed to a perturbative RF field on a bias dc, nonequilibrium corrections to the current-carrying state, including the Higgs mode—previously overlooked—significantly influence Q-values and kinetic inductance, even in the RF region. Notably, over 40 % of the current dependence of kinetic inductance is attributed to the Higgs mode. Moreover, the anti-Q-slope as a function of dc bias becomes more pronounced at higher frequencies. These findings suggest that the anti-Q-slope under strong RF fields arises from these nonequilibrium corrections in addition to DOS smearing. Such corrections, including the Higgs mode, are crucial in superconducting devices under strong currents, whether dc or RF, affecting not only SRF cavities but also devices like single photon detectors and kinetic inductance detectors. This presentation highlights key physical mechanisms and their impact on superconducting devices, including SRF cavities.

Footnotes:

[1] A. Gurevich, Phys. Rev. Lett. 113, 087001 (2014).
[2] T. Kubo and A. Gurevich, Phys. Rev. B 100, 064522 (2019).
[3] T. Kubo, Phys. Rev. Applied 22, 044042 (2024).
[4] T. Kubo, arXiv:2502.05914.

Funding Agency:

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Thursday Oral Session: B - Board: THB01 / **95**

Semi-automatic robot assisted, clean assembly of PIP-II LB650 cavity string at CEA

Author: Stéphane Berry[1]

[1] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

Corresponding Author: stephane.berry@cea.fr

Achieving optimal performance in SRF (Superconducting Radio Frequency) cavity assembly relies heavily on precise cleanroom processing, where contamination poses significant risks. Human activities, a major source of particle emissions in cleanrooms, not only threaten cavity cleanliness but also contribute to labor intensity and noise exposure. To mitigate these challenges, recent advancements in robotics offer promising solutions for automating critical steps in cavity assembly. In particular, a collaborative robot (cobot) implemented by CEA introduces automated processes such as coupler to cavity assembly, flange and bellows cleaning, and repetitive handling. The cobot, a FANUC CRX-25 6-axis arm mounted on a support frame, can operate independently and at night, significantly reducing assembly duration while ensuring consistent, reproducible results. By eliminating the need for manual operation in noisy, repetitive tasks, this cobot enhances both efficiency and technician safety, supporting higher cleanroom standards. This paper presents an overview of these automated processes, the cobot's implementation, the cavity RF cold test and the technical decisions shaping future developments in SRF cavity assembly.

Thursday Oral Session: B - Board: THB02 / **94**

Status of robotics and automation in the SRF community and real applications

Author: Laura Popielarski[1]

[1] *Facility for Rare Isotope Beams*

Corresponding Author: lpopiela@frib.msu.edu

The performance of superconducting RF (SRF) cavities is extremely sensitive to contamination by particles on the SRF surface. To mitigate this, high-pressure rinsing (HPR) with ultra-pure water is performed after surface treatment, and cavity assembly is conducted in a cleanroom environment. However, even when cleanroom suits are worn, human involvement in these processes can still introduce particle contamination.

In recent years, significant advancements have been made in the development of work robots across industries such as automotive manufacturing, semiconductor technology, and medical care, leading to increased automation. The SRF community has also embraced this trend. For example, FRIB has implemented robots for HPR, and institutions like FNAL, KEK, and Saclay are exploring robotic solutions for cavity assembly. Looking ahead, the integration of artificial intelligence (AI) is expected to enable cavity assembly that is entirely free from particle contamination while also eliminating the risk of human error. This talk will provide an overview of robotic and automated technologies related to superconducting cavities, along with examples of their practical applications.

Thursday Oral Session: B - Board: THB03 / **46**

Cavity surface inspection: automated defect detection using a short focus imaging system

Author: Sonia Mathews[1]

Co-authors: Alick Macpherson [1]; Niall Stapley [1]

[1] *European Organization for Nuclear Research*

Corresponding Author: sonia.rebecca.mathews@cern.ch

The performance of SRF cavities is critically dependent on the integrity of their inner surfaces. However, traditional inspection methods are limited by the geometry of these cavities. To overcome this challenge, a novel automated defect detection system has been developed at CERN. This system utilizes a short-focus imaging system mounted on a scanning robotic arm, enabling comprehensive and high-resolution inspection of the entire cavity surface. By combining overlapping image coverage with optical anomaly analysis, surface irregularities can be precisely identified and cataloged. Advanced algorithms, including both rule-based and machine learning models, are employed to classify defects such as scratches, inclusions, pits, and weld artifacts. This approach has been successfully tested on 1.3 GHz and 400 MHz cavities fabricated from both bare niobium and copper substrates, as well as niobium-coated cavities. Full cavity scans typically require between 3 to 20 hours, depending on cavity size, and are performed by acquiring a series of overlapping images each 10 x 15 mm. Subsequent defect detection and analysis are carried out offline as part of the automated image processing chain. This facilitates the creation of a standardized catalogue of surface defects, with images taken under consistent imaging conditions. The systematic analysis of defects can be used to develop predictive insights into defect impact on cavity performance, ultimately advancing SRF technology.

Thursday Oral Session: B - Board: THB04 / **49**

Status of the CW SRF gun development for LCLS-II-HE at FRIB

Author: John Smedley[1]

Co-authors: Alex Taylor [2]; Andre Arnold [3]; Bryan Tousignant [2]; Chris Adolphsen [1]; Chris Compton [2]; Dan Morris [2]; Daniel Gonnella [1]; Fuhao Ji [1]; James Maniscalco [1]; Jeffrey Hulbert [2]; Jie Wei [2]; Jochen Teichert [3]; John Lewellen [4]; John Wenstrom [2]; Ken Witgen [5]; Kenji Saito [2]; Kyle Elliott [2]; Laura Popielarski [2]; Liling Xiao [1]; Matthew Murphy [1]; Michael Kelly [6]; Mohit Patil [2]; Petr Murcek [3]; Philippe Piot [7]; Robert Coy [1]; Rong Xiang [3]; Samuel Miller [2]; Sang-Hoon Kim [2]; Stefan Gatzmaga [3]; Taro Konomi [2]; Ting Xu [2]; Troy Petersen [6]; Walter Hartung [2]; Wei Chang [2]; Xiaoji Du [2]; Yamen Al-Mahmoud [2]; Yoonhyuck Choi [2]; Ziye Yin [2]

[1] *SLAC National Accelerator Laboratory*

[2] *Facility for Rare Isotope Beams*

[3] *Helmholtz-Zentrum Dresden-Rossendorf*

[4] *Los Alamos National Laboratory*

[5] *Michigan State University*

[6] *Argonne National Laboratory*

[7] *Northern Illinois University*

Corresponding Author: smedley@slac.stanford.edu

A superconducting radio-frequency photo-injector (SRF-PI) can in principle operate in continuous-wave (CW) mode at high gradients with ultra-high vacuum. Using low mean-transverse-energy photocathodes, SRF-PIs could provide high-brightness, high- repetition-rate beams with long cathode lifetimes. For these reasons, an SRF-PI has been adopted for the proposed Low Emittance Injector addition to the SLAC Linac Coherent Light Source II High-Energy (LCLS-II-HE) Upgrade, which would operate in CW with bunch rates of up to 1 MHz. This new injector is a critical part of the

effort to extend the photon energy range of this new x-ray laser. A 185.7 MHz quarter-wave gun cavity and cryomodule have been developed by the Facility for Rare Isotope Beam at Michigan State University (FRIB/MSU) in collaboration with HZDR, ANL, and SLAC. A cryomodule test of the first prototype gun cavity and cold tests of a second cavity are underway at FRIB/MSU. The cavities have met the goal of 30 MV/m photocathode field in cold tests in which a photocathode was not installed. All critical cavity parameters fit very well with the simulations and a fully integrated module test with normal conducting cathodes (both metal and semiconductor) are underway.

Funding Agency:

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Thursday Oral Session: B - Board: THB05 / **34**

Cold integration of the DESY CW L-band SRF gun cavity with Cu photocathode

Author: Sonja Jaster-Merz[1]

Co-authors: Dmitry Bazyl [1]; Elmar Vogel [1]

[1] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Author: sonja.jaster-merz@desy.de

A future upgrade of the European XFEL aims for operation in a high-duty-cycle regime. The baseline electron source for the photoinjector is a continuous wave (CW) L-band superconducting radio frequency (SRF) gun cavity developed at DESY. Recently, this gun cavity with a copper (Cu) cathode mounted directly onto the backwall via threaded connections demonstrated world record peak axial electric field values of up to 50 MV/m. In this contribution, we report on the present status of the gun cavity design, describe the cold integration of the photoinjector cavity including the cryostat, tuner and solenoid magnet, and show the plans for a test stand facility to verify the beam quality produced by this SRF gun.

Thursday Oral Session: B - Board: THB06C / **128**

First beam commissioning of the bERLinPro superconducting radio-frequency (SRF) photoelectron gun

Author: Axel Neumann[1]

Co-authors: Andriy Ushakov [1]; Chen Wang [1]; Emily Jayne Brookes [1]; Ezgi Ergenlik [1]; Guido Klemz [1]; Jens Knobloch [2]; Jonas Dube [1]; Julius Kuehn [1]; Pablo Echevarria [1]; Thorsten Kamps [1]

[1] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[2] *University of Siegen*

Corresponding Author: axel.neumann@helmholtz-berlin.de

After about a decade of research, development and construction work, the bERLinPro Energy Recovery Linac project at HZB changed over into the commissioning phase and started the operation of the SRF photo-injector with the injection line of the accelerator. This system had already produced

beam from a metal photo-cathode in 2018 [1] in a dedicated test environment and was assembled in the accelerator hall after a required refurbishment and repair program [2]. The 1.3 GHz SRF gun successfully generated first photoemission beam from a high quantum efficiency (QE) Na-based multi-alkali photocathode. In this contribution, the results of the first two measurement campaigns will be shown, including a review of the SRF design, the RF commissioning, the cavity performance, especially with respect to dark current, the cathode quantum efficiency and lifetime, as well as the measured beam parameters.

Footnotes:

[1] A. Neumann et al., "The BERLinPro SRF Photoinjector System - From First RF Commissioning to First Beam", in Proc. 9th Int. Particle Accelerator Conf. (IPAC'18), Vancouver, BC, Canada, Apr. 4„ pp. 1660-1663, doi:10.18429/JACoW-IPAC2018-TUPML053
[2] Yegor Tamashevich et al 2024 Eng. Res. Express 6 025009

Funding Agency:

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Thursday Oral Session: B - Board: THB07C / **114**

Progress of assembly and installation of LIPAc SRF cryomodule under the EU–JA collaborative framework

Author: Takashi Ebisawa[1]

Co-authors: Atsushi Kasugai [1]; Eiji Kako [2]; Hiroshi Sakai [2]; Janic Chambrillon [3]; Jean-Pierre Adam [3]; Kai Masuda [1]; Kazuo Hasegawa [1]; Keitaro Kondo [1]; Nicolas Bazin [4]

[1] *National Institutes for Quantum Science and Technology*
[2] *High Energy Accelerator Research Organization*
[3] *Fusion for Energy*
[4] *Centre Antoine Lacassagne*

Corresponding Author: ebisawa.takashi@qst.go.jp

The commissioning of LIPAc (Linear IFMIF Prototype Accelerator) is ongoing at QST Rokkasho Institute for Fusion Energy within the engineering validation of the accelerator system up to 9 MeV/125 mA in continuous wave under international collaboration between Japan and Europe. Several SRF cryomodules will be required for IFMIF to accelerate deuterons from 5 MeV to 40 MeV. The prototype of the first of these cryomodules has been manufactured and will be installed and tested on the LIPAc. It holds the eight Half Wave Resonator and RF couplers to accelerate the beam and the eight superconducting solenoids to focus it. During the cryomodule assembly, several non-conformities were identified, including vacuum leaks and cryogenic pipe issues. These challenges were addressed through a coordinated effort involving Japanese and European partners. Solutions included the refabrication and repair in Japan of critical components, adhering to Japan's High Pressure Gas Safety Act and international standards. Material selection, thermal cycling treatments, magnetization assessments, and regulated welding with non-destructive tests (pressure and penetration) were jointly implemented. This poster outlines the technical approaches taken, highlights the collective efforts of the LIPAc team in resolving the encountered issues, and reports on the progress toward the successful assembly and validation of the LIPAc SRF cryomodule.

Thursday Poster Session - Board: THP01 / **246**

Status of the Mainz Energy-Recovering Accelerator (MESA)

Author: Timo Stengler[1]

Co-authors: Florian Hug [2]; Kurt Aulenbacher [3]

[1] *Institut für Kernphysik*
[2] *Johannes Gutenberg University Mainz*
[3] *Helmholtz Institute Mainz*

Corresponding Author: stengler@kph.uni-mainz.de

This contribution provides an updated overview of the Mainz Energy-Recovering Accelerator (MESA), a continuous-wave superconducting electron linac currently under construction at the Institute for Nuclear Physics at Johannes Gutenberg University Mainz. Designed to deliver high-current, highly polarized beams with energy recovery, MESA aims to support a diverse experimental program. The current status of the accelerator, with a focus on the installation of key components of the SRF infrastructure, will be presented.

Funding Agency:

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Thursday Poster Session - Board: THP02 / **279**

Upgrades to the Daresbury Laboratory Vertical Facility and testing of PIP-II HB650 cavities

Author: Andrew Blackett-May[1]

Co-authors: Alan Wheelhouse [1]; Anna Shabalina [2]; Ayo Akintola [1]; Conor Jenkins [2]; David Mason [2]; Edward Cavanagh [1]; Genfa Wu [3]; George Miller [2]; Geraint Jones [2]; HyeKyoung Park [3]; Ivan Skachko [1]; Jennifer Mutch [2]; John Hassall [2]; Joseph Ozelis [3]; Laura Grassellino [3]; Mark Pendleton [2]; Matthew Jones [1]; Oliver Poynton [2]; Paul Smith [1]; Peter McIntosh [2]; Philip Hornickel [2]; Shrikant Pattalwar [1]; Stuart Wilde [4]; Vijay Chouhan [3]; Zakia Bilques [2]

[1] *ASTeC, STFC Daresbury Laboratory*
[2] *Science and Technology Facilities Council*
[3] *Fermi National Accelerator Laboratory*
[4] *Daresbury Laboratory*

Corresponding Author: andrew.may@stfc.ac.uk

A novel vertical test facility (VTF) has been in operation at the UKRI-STFC Daresbury Laboratory since 2019. This VTF tests jacketed SRF cavities in a horizontal configuration at 2 K. Originally designed and operated for 704 MHz high-beta cavities for ESS, the facility has now been upgraded and expanded to test 650 MHz high-beta cavities for PIP-II, including fast cooldown capability (>20 K/min) for magnetic flux expulsion. This paper reports on the new design, commissioning, and operation of the facility.

Funding Agency:

UKRI-STFC

Thursday Poster Session - Board: THP03 / **264**

Beam diagnostics and RF cavity operation during SCL3 beam commissioning at RAON

Author: Jangwon Kwon[1]

[1] *Institute for Basic Science*

Corresponding Author: jwkwon@ibs.re.kr

RAON is a heavy ion accelerator consisting of a cryomodule containing a superconducting cavity in the SCL3 section and a warm section with a quadrupole magnet and a diagnostic chamber. Two types of superconducting RF cavities are utilized, arranged in three types of cryomodules: the 81.25 MHz quarter-wave resonator (QWR) and the 162.5 MHz half-wave resonator (HWR). In 2024, beam commissioning was carried out with the entire SCL3 section in operation. RF cavity tuning was successfully achieved using a systematic phase scan procedure. During this period, an argon beam with a current of 40 μA and a sodium beam with a rate of ~10,000 particles per second were delivered to the experimental area. The accelerator was operated at an RF power of 4 W and a maximum duty cycle of 10%. The beam diagnostic system included beam position monitors (BPM), wire scanners (WS), Faraday cups (FC), beam loss monitors (BLM), and beam loss collectors (BLC). All current-based diagnostic signals, including BLC and Faraday cup signals, were processed through the mTCA standard-based data acquisition system. This poster describes the integrated operation of the diagnostic and RF systems and summarizes key observations made during the commissioning of the SCL3 linear accelerator.

Funding Agency:

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Thursday Poster Session - Board: THP04 / **303**

Horizontal cryostat testing of the ORNL Spallation Neutron Source (SNS) Proton Power Upgrade (PPU) cryomodules at Jefferson Lab

Author: Michael McCaughan[1]

Co-authors: Edward Daly [1]; John Fischer [1]; Michael Drury [1]; Naeem Huque [1]

[1] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: michaelm@jlab.org

Oak Ridge National Laboratory (ORNL) is in the process of upgrading its Spallation Neutron Source (SNS) Linear Accelerator in order to double the total machine power from 1.4 to 2.8 MW. This Proton Power Upgrade (PPU) makes use of an added 7 4-cavity cryomodules to its SRF Linac to raise the machine energy to a total 1.3 GeV (with one additional module produced as a ready spare). Jefferson Lab was contacted to produce these modules with vertical testing, manufacturing, and limited horizontal testing of the cryomodules executed at Jefferson Lab and final high-power testing occurring locally at ORNL. This paper will detail ensemble tuner testing results, passbands, and loaded Q results obtained for the 8 modules which have been manufactured.

Funding Agency:

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Thursday Poster Session - Board: THP05 / **138**

Beam envelope measurements using beam position monitors for low-beta superconducting linear accelerator

Author: Takahiro Nishi[1]

Co-authors: Kazunari Yamada [1]; Naruhiko Sakamoto [1]; Osamu Kamigaito [1]; Ryo Koyama [2]; Taihei Adachi [1]; Tamaki Watanabe [1]

[1] *RIKEN Nishina Center*

[2] *SHI Accelrator Service Ltd.*

Corresponding Author: takahiro.nishi@riken.jp

Accurate monitoring of beam dynamics in superconducting linear accelerators (linacs) is important for minimizing beam losses and maintaining stable operation. In superconducting sections, however, destructive diagnostics must be avoided to prevent issues such as particulate contamination and outgassing, which makes direct beam envelope measurements particularly difficult. This work introduces a non-destructive approach that leverages beam position monitors (BPMs) to infer the transverse beam envelope by measuring the quadrupole moment of the beam profile. Although the principle was initially proposed in the 1980s, its adoption—especially for hadron beams—has remained limited due to insufficient signal sensitivity and the geometric limitations of conventional BPM designs. To address these challenges, we utilized BPMs with a cos(2θ) electrode structure, which provide enhanced sensitivity to quadrupole components and are particularly effective for low-β heavy ion beams. This technique was implemented in the superconducting RIKEN linac (SRILAC), where data from eight BPMs were combined with transfer matrix modeling and supplementary wire scanner measurements. The estimated beam envelopes showed good agreement with results from standard quadrupole scans, validating the proposed method as a practical tool for non-destructive, routine beam diagnostics in superconducting accelerator systems.

Thursday Poster Session - Board: THP06 / **191**

The operation of ARIEL e-LINAC RF system

Author: Yanyun Ma[1]

[1] *TRIUMF*

Corresponding Author: mayanyun@triumf.ca

The Advanced Rare Isotope Laboratory (ARIEL) at TRIUMF will utilize a high-power electron beam to produce radioactive ion beams through photo-fission. Currently, the 30 MeV section of the ARIEL electron linear accelerator (e-Linac)—a 1.3 GHz superconducting RF (SRF) system—includes the injector cryomodule (ICM), which houses a single nine-cell cavity, and the first accelerator cryomodule (ACM1), configured with two cavities. This paper focuses on recent progress toward high-power operation. At the beginning of 2025, the system achieved stable, continuous operation for three consecutive days.

Thursday Poster Session - Board: THP07 / **190**

Q degradation in operation in ISAC-II SC linac

Author: Zhongyuan Yao[1]

Co-authors: David Kishi [1]; Devon Lang [1]; James Keir [1]; Johnson Cheung [1]; Philipp Kolb [1]; Robert Laxdal [1]; Rowan Bjarnason [1]; Spencer Kiy [1]

[1] *TRIUMF*

Corresponding Author: zyyao@triumf.ca

Quality factor (Q) of SRF cavities is one of the essential parameters in continuous wave accelerator operation. Q degradation has been observed in the operation of ISAC-II superconducting heavy ion linac. Other than the well-known mechanisms, such as field emission and trapped magnetic flux, the past eight years statistics reveals gas molecules in the beam line caused measurable Q drops after a few months'operation. This paper will describe the observations on ISAC-II linac, analyze data from operation and accidents, and discuss the results of the proof of principle tests.

Thursday Poster Session - Board: THP08 / **192**

Progress of prototype RFD crab cavity string assembly for HL-LHC at TRIUMF

Author: Zhongyuan Yao[1]

Co-authors: Ben Matheson [1]; Bhalwinder Waraich [1]; Devon Lang [1]; James Keir [1]; Oliver Law [1]; Philipp Kolb [1]; Robert Laxdal [1]; Ruminder Sekhon [1]

[1] *TRIUMF*

Corresponding Author: zyyao@triumf.ca

The High-Luminosity Large Hadron Collider (HL-LHC) project is to increase the integrated luminosity by a factor of 10 beyond the LHC's design value. TRIUMF is collaborating with CERN, UK and US-AUP to provide five RF dipole (RFD) crab cavity cryomodules to HL-LHC as Canadian contribution. A prototype cryomodule (TCM0) is being assembled to qualify TRIUMF's infrastructure, procedure and tooling. The experience and lessons learned on TCM0 will be applied to the series production cryomodules. This paper will give updates of the progress of TCM0 string assembly, including infrastructure readiness, tooling and fixture readiness, prototype cavity acceptance, and the status of the string assembly.

Thursday Poster Session - Board: THP09 / **207**

Magnetic field sensitivity of a QWR under different cooldown dynamics

Author: Philipp Kolb[1]

Co-authors: Robert Laxdal [1]; Will Stokes [2]; Zhongyuan Yao [1]

[1] *TRIUMF*

[2] *TRIUMF; University of Victoria*

Corresponding Author: kolb@triumf.ca

The sensitivity of the surface resistance of SRF cavities depends on several aspects, such as the specific surface and heat treatment of the cavity. The the cooldown dynamics as the cavity transitions into the superconducting (sc) state also influence the performance if there is an external magnetic field. Both temperature gradient across the cavity and speed of the superconducting front have been shown to be impacting the performance. But also the direction of movement of the superconducting front impacts the performance as magnetic fields are pushed by the superconducting front. Quarter-wave resonators (QWR) have a complex geometry with their closed inner conductor. Depending on the cooldown dynamics, the magnetic flux could be pushed to either the tip of the inner conductor with low rf surface currents, or to the short plate of the cavity with high rf surface currents. In previous measurements of the TRIUMF multimode QWR the SC front moves from outer conductor to the inner conductor. In the presented paper, the direction has been reversed to show the effects of the direction of movement of the sc front on the cavity performance.

Thursday Poster Session - Board: THP10 / **107**

Thermal and magnetic flux dynamics in superconducting niobium cavities: implications for the threshold field limit

Author: Ravikumar Gurazada[1]

Co-authors: Chandrasekhar Angani [1]; Sindhunil B. Roy [2]; Akira Yamamoto [3]; Ganapati Myneni [1]

[1] *GITAM University*

[2] *Ramakrishna Mission Vivekananda Educational and Research Institute*

[3] *KEK Applied Research Laboratory*

Corresponding Author: rgurazad@gitam.edu

While the fabrication technology superconducting Niobium cavities is advanced, a wide gap exist between the theoretical threshold field H_{sh} and the observed values. The reasons behind this discrepancy continue to pose intriguing questions, highlighting the need for further investigation. While material properties undoubtedly influence performance, we believe that the intricate dynamics of thermal and magnetic flux diffusion play a crucial role in limiting H_{sh}.

A notable peculiarity arises from the boundary conditions imposed on the niobium sheet used to fabricate accelerator cavities. The magnetic field is applied at the inner surface, while the outer surface is maintained at a constant temperature. Near the inner surface, the magnetic field can be formally expressed as: $B_a exp(-x/\lambda_e)$, where λ_e, the effective complex penetration depth, is derived using the two-fluid model: $\lambda_e = \lambda_L(1 - in_n\omega\tau_n/n_s)^{-1/2}$, where, $n_n(n_s)$ is normal (superconducting) carrier density, ω and τ_n are field frequency and scattering time of normal carriers, respectively. To further explore this phenomenon, we will present our calculations by self-consistently solving the steady-state heat diffusion equation: $\nabla^2 T(\vec{r}) = -Q(\vec{r})/k$. $T(\vec{r})$ is fixed at the outer surface of the cavity, $Q(\vec{r})$ - the local heat generated by the RF fields, k - thermal conductivity of niobium in its superconducting state.

Funding Agency:

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Thursday Poster Session - Board: THP11 / **152**

Role of niobium purity and thermal parameters in SRF cavity optimization

Author: Arup Ratan Jana[1]

Co-authors: Abhay Kumar [2]; Vinit Kumar [2]; Ravikumar Gurazada [3]; Ganapati Myneni [3]; Sindhunil Barman Roy [4]

[1] *Variable Energy Cyclotron Centre*

[2] *Raja Ramanna Centre for Advanced Technology*

[3] *GITAM University*

[4] *Ramakrishna Mission Vivekananda Educational and Research Institute*

Corresponding Author: rgurazad@gitam.edu

In continuous mode operation, performance of normal-conducting copper RF cavities is limited by high power dissipation around 100 kW/m, needed there for achieving a modest 2 MV/m gradient. In contrast, superconducting RF (SRF) cavities can easily exceed 15 MV/m under similar conditions due to nominal Ohmic losses, thus making them ideal for high-duty accelerators like SNS and ADSS.

We are pursuing a study*, in which a magneto-thermal analysis of niobium (Nb)-based SRF cavities, examines how the intrinsic properties like BCS resistance, thermal conductivity, and Kapitza resistance affect the performance of these cavities. These parameters are evaluated as functions of temperature, RF magnetic field, and material purity, better represented by normal-state conductivity than by residual resistivity ratio (RRR).

Our initial results show that cavities of RRR 100 grade niobium can provide high threshold magnetic field values and quality factors. Besides, a reduced wall thickness there, viable because of enhanced material strength, can result in an increase in thermal efficiency. Our study also indicates that defining material specifications for Nb-cavities in terms of normal-state conductivity and thermal diffusivity, might be a more accurate framework than RRR alone.

Footnotes:

*Jana A R, Kumar A, Kumar V and Roy S B.. Pramana-J Phys 93, 51 (2019). https://doi.org/10.1007/s12043-019-1813-4

Thursday Poster Session - Board: THP12 / **52**

Unveiling the interplay: cold work, recrystallization, and flux expulsion in SRF cavities

Author: Pashupati Dhakal[1]

Co-authors: Bashu Khanal [2]; Gianluigi Ciovati [1]; Peter Lee [3]; Santosh Chetri [3]; Shreyas Balachandran [3]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *Old Dominion University*

[3] *Florida State University*

Corresponding Author: schetri@fsu.edu

The fabrication of SRF cavities from sheet materials includes deep-drawing, electron beam welding, chemical and mechanical polishing, high-temperature heat treatment, and material diffusion. The performance of these cavities is frequently constrained by magnetic flux trapping. In this presentation, we thoroughly examine how recrystallization influences flux expulsion in SRF cavities, using

cold-worked niobium sheets from various suppliers. Our findings reveal that cold-worked sheets enhance flux expulsion, especially at lower heat treatment temperatures, by promoting improved recrystallization. In particular, a traditionally fabricated Nb cavity half-cell from an annealed polycrystalline Nb sheet after an 800 C heat treatment leads to a bi-modal microstructure that ties in with flux trapping and inefficient flux expulsion. This non-uniform microstructure is related to varying strain profiles along the cavity shape. A novel approach to prevent this non-uniform microstructure is presented by fabricating a 1.3 GHz single cell Nb cavities with a cold-worked sheet and subsequent heat treatment leading to better flux expulsion after 800 C/3 h.

Funding Agency:

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Thursday Poster Session - Board: THP13 / **127**

Study of interstitial oxygen concentration near surface of Mid-T heat treated Nb SRF cavities: frequency shift analysis

Author: Rezvan Ghanbari[1]

Co-authors: Christopher Bate [2]; Detlef Reschke [2]; Getnet Deyu [1]; Hans Weise [2]; Karol Kasprzak [2]; Lea Steder [2]; Marc Wenskat [2]; Mateusz Wiencek [2]; Wolfgang Hillert [1]

[1] *Universität Hamburg*

[2] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Author: rezvan.ghanbari@desy.de

Mid-T heat treatment promotes the dissolution of surface native niobium oxide into bulk niobium and increases the interstitial oxygen concentration in the near surface layer of niobium, resulting in an improved quality factor for niobium SRF cavities at moderate accelerating fields. This study examines the average interstitial oxygen concentration within the effective magnetic field penetration depth by analyzing the total resonance frequency shift below the critical temperature and the surface resistance above it. The interstitial oxygen distribution along the depth for various heat treatment recipes is evaluated, revealing improved uniformity with increasing heat treatment temperature and conditions that cause oxygen diffusion to extend beyond the layers governing electromagnetic properties are identified. Furthermore, an anomalous frequency dip below the critical temperature is observed, with findings demonstrating a strong correlation between oxygen concentration and the dip features. This study confirms the known linear relationship between critical temperature reduction of niobium and increased interstitial oxygen concentration, yielding the same reported coefficient. Moreover, examining the effective diffusion length derived from the thermal profile of mid-T heat treatments and the estimated total oxygen content in the native pentoxide layer, with certain simplified assumptions, shows strong agreement with the oxygen concentration values obtained in this study.

Thursday Poster Session - Board: THP14 / **314**

Depth-resolved characterization of the magnetic field screening in superconducting RF materials near the critical field

Author: Robert Laxdal[1]

Co-authors: Edward Thoeng [2]; Md Asaduzzaman [3]; Philipp Kolb [1]; Ryan M. L. McFadden [4]; Tobias Junginger [1]; W. Andrew MacFarlane [2]

[1] *TRIUMF*

[2] *TRIUMF; University of British Columbia*

[3] *University of Victoria*

[4] *University of Victoria; TRIUMF*

Corresponding Author: lax@triumf.ca

The new "β-SRF" facility at TRIUMF allows for the near surface characterizations of materials with β-radiation-detected nuclear magnetic resonance (β-NMR) in applied magnetic fields up to 200 mT parallel to the sample surface. The unique facility can probe the local magnetic field within the first 100 nm of the surface and allows , for example, to measure the evolution of the Meissner screening profile as a function of applied parallel field right up to the critical field of niobium. It is the only place in the world where such a direct measurement of the local magnetic field is possible near the critical field and is ideal for the characterization of new doping treatments or layered systems. First measurements on two Nb samples one with a standard baseline treatment and with an O-doped treatment have been measured. The samples show contrasting evolution in their magnetic field screening as the applied field is increased up to 200 mT. The method and results will be summarized and the interpretation discussed utilizing recent theories.

Footnotes:

Thoeng, E., Asaduzzaman, M., Kolb, P. et al. Depth-resolved characterization of Meissner screening breakdown in surface treated niobium. Sci Rep 14, 21487 (2024). https://doi.org/10.1038/s41598-024-71724-5

Funding Agency:

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Thursday Poster Session - Board: THP15 / **260**

Development of niobium 3 GHz single-cell cavity for superconducting thin film research

Author: Yasuhiro Fuwa[1]

Co-authors: Ayaka Hattori [2]; Hayato Ito [3]; Ryo Katayama [3]; Takayuki Kubo [3]; Takayuki Saeki [3]; Yoshihisa Iwashita [4]

[1] *Japan Atomic Energy Agency*

[2] *National Institute of Technology*

[3] *High Energy Accelerator Research Organization*

[4] *Osaka University*

Corresponding Author: kataya@post.kek.jp

The introduction of thin film structures into superconducting cavities is theoretically predicted to improve performance, and experimental verification is now required. In this study, we are developing a relatively small and easy-to-handle niobium-made 3 GHz single-cell cavity to verify the effects of introducing thin film structures. We performed vertical measurements on the 3 GHz single-cell cavity after applying standard BCP and EP treatments, and obtained baseline data prior to the introduction of thin film structures. In this presentation, we report on the longitudinal measurement setup and results for the 3 GHz cavity, as well as our future research plans.

Thursday Poster Session - Board: THP16 / **262**

Impact of initial cold work on the bulk microstructure and flux expulsion performance of SRF Nb cavities

Author: Santosh Chetri[1]

Co-authors: Bashu Khanal [2]; Matthew Carl [3]; Nathan Lannoy [3]; Pashupati Dhakal [4]; Peter Lee [1]; Shreyas Balachandran [1]; Trent Boritz [1]

[1] *Florida State University*

[2] *Old Dominion University*

[3] *ATI Specialty Alloys & Components*

[4] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: schetri@fsu.edu

Recent advances in understanding the subsurface microstructure and microchemistry of niobium (Nb) have led to significant improvements in the quality factor (Q0) of superconducting radiofrequency (SRF) cavities. Beyond traditional surface treatments, emerging evidence highlights the critical role of the bulk microstructure, particularly in influencing the trapping and expulsion of residual magnetic flux during cooldown. We explore the possibilities to change the bulk microstructure by deep-drawing high-purity, cold-rolled Nb sheets into half-cells and fabricating cavities. Notably, forming half-cells starting with a cold-worked Nb sheet prior to heat treatment yields a more uniform and homogeneous microstructure, which correlates with enhanced flux expulsion and improved Q0. In this work, we systematically investigated the effects of varying degrees of cold work followed by heat treatment, on the microstructural evolution of SRF-grade Nb. We also demonstrate the feasibility of fabricating cavities from these cold-worked Nb sheets and assess their flux expulsion behavior. The results demonstrate that tailoring the initial deformation state of Nb offers a promising pathway to consistently optimize SRF cavity performance.

Funding Agency:

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Thursday Poster Session - Board: THP17 / **281**

RaSTA 2.0 - development of a compact sample test cavity for surface resistance measurements

Author: Sebastian Keckert[1]

Co-authors: Felix Kramer [1]; Jens Knobloch [2]; Oliver Kugeler [1]

[1] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[2] *University of Siegen*

Corresponding Author: sebastian.keckert@helmholtz-berlin.de

RaSTA, the Rapid Superconductor Test Apparatus, is a sample test cavity project at HZB. It shares the sample geometry and the calorimetric measurement principle with the QPR but is targeted at quicker turnaround times and a more compact footprint at higher operating frequency. RaSTA 2.0 features a niobium coated copper cavity allowing for higher RF field levels and better thermal stability. The outer dimensions have been reduced to fit the system inside a compact cryostat; sample

handling and tooling have been revised for reduced overall complexity. RaSTA can be operated without radiation shielding and the entire system is intended to be transferable to labs without extensive SRF infrastructure. We present the design and construction of RaSTA 2.0 together with operating considerations and first data obtained with the new cavity.

Thursday Poster Session - Board: THP18 / **291**

Point defects in Nb-based superconducting films probed by positron annihilation spectroscopy

Author: Sebastian Klug[1]

Co-authors: Maik Butterling [2]; Andreas Wagner [1]; Maciej Oskar Liedke [1]

[1] *Helmholtz-Zentrum Dresden-Rossendorf*

[2] *Delft University of Technology*

Corresponding Author: s.klug@hzdr.de

Positron annihilation spectroscopy (PAS) is a powerful and precise tool to study atomic-scale defects in a wide range of materials, especially superconductors. The PAS methods available at the user facility radiation source ELBE (HZDR, Germany) enable analysis of point defects and their agglomerations including within the range of micro- and mesopores. The extended defects and their complexes with vacancies as well as point defect - impurity associates are detectable and sensitivity of positrons to these shallow traps is enhanced by cryogenic temperature measurements. Positrons quantify defect microstructure characteristics as density, type, and local atomic chemistry. PAS has proven to be highly effective in characterizing vacancy-hydrogen complexes during low temperature baking * as well as for vacancy kinematics and evolution of point defects and native Nb oxides for baking at larger temperatures **.

In this contribution, defect microstructure of DC magnetron sputtered Nb and Nb3Sn thin films will be discussed, supplemented with conventional characterization methods such as XRD and vibrating sample magnetometry (VSM). The combination of these complementary techniques will provide correlations between sputter deposition parameters, e.g., deposition pressure, gas flows, etc., defects, crystal phases, and superconducting characteristics (Tc, Hc). Our long-term goal is to enable in-situ PAS during sample processing to study defect formation and their evolution.

Footnotes:

*M. Wenskat et al., Sci. Rep. 10 (2020) 8300. **M. Wenskat et al., Phys. Rev. B. 106 (2022) 094516.

Funding Agency:

BMFTR (Federal Ministry of Research, Technology and Space).
HZDR (Helmholtz-Zentrum Dresden-Rossendorf e.V.).

Thursday Poster Session - Board: THP19 / **91**

RF and DC vortices in superconductors studied with time-dependent Ginzburg-Landau theory

Author: Chung-Yang Wang[1]

Co-author: Steven Anlage [1]

[1] *University of Maryland, College Park*

Corresponding Author: anlage@umd.edu

Time-dependent Ginzburg-Landau (TDGL) numerical simulations can capture vortex nucleation and motion, as well as proximity effects, at high frequencies in superconductors.† We use TDGL to study the nucleation of RF semi-loop vortices in Niobium in the presence of surface defects when the material is subjected to an intense RF magnetic field arising from a near-field microwave frequency dipole source.‡ We also simulate the case of trapped dc magnetic vortices near the surface of a superconductor being stimulated by the nearby microwave magnetic dipole.§ These simulations also yield the second- and third-harmonic signal responses produced by the superconductor and captured by the near-field microwave probe. The results of such simulations are in good agreement with data and provide an excellent "digital twin"of our near-field microwave microscope. This combined simulation and measurement technique provides access to vortex dynamics at the micron scale, such as depinning events and spatially-resolved pinning properties, as demonstrated in measurements on a Niobium film with an antidot flux pinning array. We use these validated TDGL simulations to address "what-if"questions about the response of superconducting surfaces and vortices to intense RF magnetic fields under a variety of conditions, and some of these results will be presented.

Footnotes:

† B. Oripov, S. M. Anlage, Phys. Rev. E 101, 033306 (2020).
‡ C.-Y. Wang, C. Pereira, S. Leith, G. Rosaz, S. M. Anlage, Phys. Rev. Applied 22, 054010 (2024).
§ C.-Y. Wang, S. M. Anlage, arxiv:2503.02811.

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Thursday Poster Session - Board: THP20 / **116**

Molecular dynamics study on the mechanical behavior of pure and alloyed niobium for superconducting RF cavity applications

Author: Taeyoung Yoon[1]

[1] *Changwon National University*

Corresponding Author: tyyoon@changwon.ac.kr

Niobium (Nb) has long been recognized as the primary material for superconducting radio-frequency (SRF) cavities due to its excellent superconducting properties and mechanical formability. However, improving its structural stability under cryogenic operating conditions and high electromagnetic loads remains a key challenge. In this study, we employ molecular dynamics (MD) simulations to investigate the mechanical behavior of three candidate materials: single-crystalline niobium, low-alloyed Nb-Zr, and Nb-Mo systems. Each system is modeled as a cubic specimen subjected to 20 % uniaxial compression, and their mechanical responses are analyzed through stress-strain curves, dislocation evolution, and local atomic structure classification via Common Neighbor Analysis (CNA). Alloying effects on yield strength, plastic deformation mechanisms, and microstructural stability are systematically evaluated. The simulation results provide atomistic insights into how minor alloying additions influence defect formation and dislocation motion, which are critical factors in maintaining cavity performance under thermal and mechanical stress. This study aims to propose a guideline for alloy composition optimization in SRF cavity design by identifying compositions that enhance mechanical resilience while preserving favorable superconducting characteristics. The findings are expected to support the development of next-generation SRF cavity materials with improved durability and performance.

Thursday Poster Session - Board: THP21 / **211**

Study of multilayer thin-film structures in superconducting acceleration cavities

Author: Taisei Sasaki[1]

Co-authors: Takayuki Saeki [2]; ryo katayama [2]; Takayuki Kubo [2]; Yoshihisa Iwashita [3]; Yasuhiro Fuwa [4]; Tomoyuki Sanuki [5]

[1] *Tohoku University*

[2] *High Energy Accelerator Research Organization*

[3] *Osaka University*

[4] *Japan Atomic Energy Agency*

[5] *Jikei University School of Medicine*

Corresponding Author: sasaki.taisei.r4@dc.tohoku.ac.jp

Currently, 1.3 GHz Nb superconducting elliptical cavities have achieved accelerating gradients of Eacc ≈ 40 MV/m. In contrast, theoretical predictions suggest that accelerating cavities with multilayer thin-film structures on their inner surfaces might reach gradients of Eacc ≈ 100 MV/m. Such significant performance improvements would represent a major advancement not only in high-energy physics experiments, but also in industrial applications. Previous studies have confirmed the feasibility and effectiveness of forming multilayer thin films on flat samples. The next step is to develop film-deposition techniques suitable for the inner surfaces of cavities. In particular, developing specialized cathodes for sputtering alloy films is a key challenge. Therefore, simulations of sputtering are conducted to analyze the distribution and thickness of the resulting films for the cathode design. Furthermore, by exploring various experimental conditions, thin-film deposition tests will be carried out efficiently for evaluating the performance of multilayer structures. This presentation reports in detail on studies related to thin-film depositions inside superconducting accelerator cavities.

Thursday Poster Session - Board: THP22 / **265**

Thermo-mechanical testing results for IC-DX ultra-low thermal expansion alloy at cryogenic temperature

Author: Tomohiro Yamada[1]

Co-authors: Ashish Kumar [1]; Masashi Yamanaka [1]

[1] *High Energy Accelerator Research Organization*

Corresponding Author: ytomohi@post.kek.jp

Thermal shrink of materials is always an obstacle when designing cryogenic systems. In superconducting cavity cryomodules, some adopt reference bars, which are made by Invar, to keep cavities' position same at cryogenic temperature from room temperature. Linear expansion of Invar from 300 K to 2 K is about 0.04 %, resulting in approximately 5 mm of thermal shrink for the 12.6 m ILC cryomodule, for example. Since the less the reference bar shrinks, the better, our search for a new material led us to a material called IC-DX. It has 3~4 times smaller thermal shrink than Invar and has about 180 GPa of Young's modulus at room temperature, which is 1.5 times larger than that of conventional Invar. It was known that IC-DX did not change to martensitic structure when cooled to cryogenic temperatures, but tensile tests, thermal conductivity measurements, and Charpy impact tests at liquid helium temperatures had not been conducted. In this study, tensile and Charpy impact tests were conducted at room temperature, liquid nitrogen temperature, and liquid helium temperature, and thermal conductivity measurements were conducted at 4-50 K. In this presentation, we report on these results.

Thursday Poster Session - Board: THP23 / **160**

Fabrication of 1.3 GHz MgB2 superconductor-on-copper cavity using hybrid physical-chemical vapor deposition

Author: Xiaoxing Xi[1]

Co-authors: Ke Chen [1]; Xiaojun Xu [1]

[1] *Temple University*

Corresponding Author: xiaoxing@temple.edu

Superconductor MgB2 has a Tc of 40 K, and its materials parameters suggest that SRF cavities with higher Q, higher gradient, and higher operation temperatures than Nb cavities can potentially be made from MgB2. We present our ongoing efforts towards the development of MgB2-coated SRF cavities. Thick MgB2 films, up to 5 um in thickness, were deposited onto 1.3 GHz Tesla-type copper RF cavities using a hybrid physical-chemical vapor deposition (HPCVD) process. The mock cavities were fabricated through deep drawing. A pair of clamshell resistive heaters was employed for heating the cavity during the coating. MgB2 films grown on 1 cm × 1 cm copper substrates attached to the inner wall of the cavities exhibited a critical temperature of up to 38 K, as determined by AC susceptibility measurements. Uniform MgB2 film coatings were achieved by moving the Mg and B source in tandem with computerized control of deposition parameters, including cavity temperatures and gas flow rates. The MgB2 films were also characterized by RF surface resistance measurements.

Funding Agency:

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Thursday Poster Session - Board: THP24 / **142**

1.3 GHz thin film cavity testing at daresbury laboratory

Author: Daniel Seal[1]

Co-authors: Amir Mogheyseh [2]; Christopher Benjamin [3]; Graeme Burt [2]; Harry Marks [2]; Liam Smith [3]; Oleg Malyshev [3]; Oliver Poynton [3]; Reza Valizadeh [3]; Stephane Simon [4]

[1] *Science and Technology Facilities Council*

[2] *Lancaster University; Cockcroft Institute*

[3] *Science and Technology Facilities Council; Cockcroft Institute*

[4] *University of Liverpool; Cockcroft Institute*

Corresponding Author: daniel.seal@stfc.ac.uk

At Daresbury Laboratory, two new cryogenic facilities have been designed, built and tested for RF testing of 1.3 GHz thin film coated cavities. The first facility is a high power vertical test stand that has been designed to test both single-cell and multi-cell cavities in LHe at 2 and 4.2 K. However, this facility is shared with other projects, limiting the number of tests per year. To ensure that only good cavities are tested in this facility, a second test stand has also been developed for high throughput cavity testing. This uses a pulse-tube cryocooler with a cooling capacity of 2.7 W at 4.2 K. The simple design and operation enables qualification of up to 2 cavities per week. Details of these facilities and results from RF cavity measurements are presented.

Thursday Poster Session - Board: THP25 / **6**

Cold spray additive manufactured copper as substrate for thin film-SRF cavities

Author: Fritz Motschmann[1]

Co-authors: Bertrand Baudouy [1]; Christophe Verdy [2]; Fabien Eozénou [1]; Thomas Proslier [3]

[1] *Commissariat à l'Energie Atomique*

[2] *Université de technologie de belfort-montbéliard*

[3] *Université Paris-Saclay*

Corresponding Author: fritz.motschmann@cea.fr

Recent advances in additive manufacturing promise interesting possibilities for the design and fabrication of superconducting radio frequency (SRF) cavities. Cold Spray Additive Manufacturing (CSAM) is one candidate that would allow for rapid built times, realization of integral cooling structures, deposition of different materials and an easy upscaling with available equipment. As it is the case for any present AM-method, we need to address limitations and challenges regarding microstructure and surface quality of the built material towards an actual application. This work focuses on the experimental analysis of pure copper manufactured by CSAM regarding their mechanical, microstructural and physical properties that are key for the operation of SRF-cavities. The present state of the art cold sprayed copper demonstrates a dense microstructure with a low defect density. Residual resistance ratios and mechanical properties in the range of the specifications of conventionally used oxygen-free copper can be obtained with adequate post-heat treatments. Special attention is also paid to the condition and possible improvement routes for the RF-facing surface of CSAMed copper cavities.

Thursday Poster Session - Board: THP26 / **110**

European thin film roadmap

Author: Oleg Malyshev[1]

Co-authors: Claire Antoine [2]; Cristian Pira [3]; Oliver Kugeler [4]; Thomas Proslier [2]; Reza Valizadeh [5]

[1] *Science and Technology Facilities Council*

[2] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

[3] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro*

[4] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[5] *Daresbury Laboratory*

Corresponding Author: oleg.malyshev@stfc.ac.uk

Superconducting thin film (TF) technology for Superconducting readio-frequency(SRF) applications is under intense development in many research centres around the world. TF SRF technology can not only drastically reduce cryogenic costs but also opens the door to simplified alternative cooling schemes with reduced helium inventory. Up to today, TF development have been considered within two High Energy Roadmaps (CERN and Snowmass), without taking into account other possible applications. Within the framework of the European H2020 project IFAST, an "European TF-SRF Roadmap"has been developed that also covers all applications aspects including high-intensity hadron/neutron sources, light sources, cavity detectors, quantum computing or emerging fields like compact accelerators poised to revolutionize industrial processes and medical diagnostics, and commercial applications. This work proposes a comprehensive approach focused on the expertise and collaborative network that has been built in Europe and in the entire world over the past years. Ten priority topics have been identified on TF development. This talk will briefly describe the main feature of the roadmap and expecting for returns from the international community to improve our initial document and disseminate it on a larger scale.

Footnotes:

Thin Film SRF

Funding Agency:

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Thursday Poster Session - Board: THP28 / **188**

Contamination of the Nb3Sn evaporation coating furnace at IHEP: analysis of causes and solutions

Author: Baiqi Liu[1]

Co-authors: Weimin Pan [2]; Feisi He [1]; Chao Dong [1]; song jin [1]; Jiyuan Zhai [1]; Peng Sha [1]

[1] *Institute of High Energy Physics*

[2] *Chinese Academy of Sciences*

Corresponding Author: liubq@ihep.ac.cn

In 2020, IHEP-CAS built a dual-vacuum furnace specifically used for Nb3Sn evaporation coating experiments. After four years of use and more than 80 experiments, in August 2024, it was found that the coated cavity produced by this furnace had serious field emission. After discussion and analysis, we suggested that the contamination originated from the coating furnace. By disassembling the inner niobium chamber, it was discovered that the problem lied in the three-face sealing structure, where the fluororubber sealing ring had severely aged at the niobium cylinder side due to high temperatures. Subsequently, the inner parts of the furnace were thoroughly cleaned, and the three-face sealing structure was modified to a two-sided sealing structure, with the niobium cylinder sealing side being removed. Once the renovation was completed and the furnace resumed operation, its performance returned to its previous state.

Funding Agency:

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Thursday Poster Session - Board: THP30 / **187**

Enhancing superconducting radio-frequency performance with high-throughput method-assisted FeSe1-xTex coated Nb films

Author: Chao Dong[1]

Co-author: Peng Sha [1]

[1] *Institute of High Energy Physics*

Corresponding Author: dongchao@ihep.ac.cn

Bulk Nb superconducting radio-frequency (SRF) cavities are widely utilized in particle accelerators, however, their accelerating gradient and overall performance are limited by the superheating field (Bs). To overcome this theoretical limit, we aim to develop innovative multilayer structures. Iron-based superconductors are considered promising coating materials for such multilayer structures, however, detailed studies on this topic remain scarce. In this research, we fabricated FeSe1-xTex-coated Nb planar films and characterized their structural, electrical transport and magnetic properties to explore the feasibility of this superconductor-superconductor bilayer. To efficiently identify the optimal Te doping level, advanced high-throughput film synthesis techniques were employed to fabricate composition-spread FeSe1-xTex film (x = 0 - 1) on a piece of Nb film, followed by micro-region structural and transport characterizations. The results demonstrate that under optimal doping, the Bc1 of FeSe1-xTex coated Nb films is significantly enhanced, while its Tc is comparable to that of bulk Nb. Through high-throughput methods, this work provides valuable technical parameters and insights into vortex penetration behavior, laying the foundation for the development of future SRF cavities based on iron-based superconducting films.

Thursday Poster Session - Board: THP31 / **228**

Additive manufacturing for seamless 6 GHz Nb/Cu cavity

Author: Davide Ford[1]

Co-authors: Adriano Pepato [2]; Cristian Pira [3]; Dorothea Fonnesu [3]; Eduard Chyhyrynets [3]; Fabrizio Stivanello [3]; Giorgio Keppel [3]; Pietro Rebesan [4]; Silvia Candela [4]; Valentina Candela [4]

[1] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro*

[2] *Univ. degli Studi di Padova*

[3] *Istituto Nazionale di Fisica Nucleare*

[4] *INFN- Sez. di Padova*

Corresponding Author: davide.ford@lnl.infn.it

Additive Manufacturing (AM) offers a unique way of fabricating components with intricate geometries and enables the use of materials that are otherwise difficult to machine or process due to high melting points. Within this context, recent work at INFN-LNL and INFN-Padova focused on the fabrication of a seamless 6 GHz copper cavity using AM techniques. This study investigates the feasibility of fabricating a geometrically complex structure (such as an elliptical RF cavity) without internal supports, while demonstrating compatibility with ultra-high vacuum (UHV), superconducting coating, and cryogenic operation. The cavity underwent successful internal polishing via Plasma Electrolytic Polishing (PEP) and passed standard leak tests. After polishing, a thin niobium (Nb) coating (~ 3 µm) was deposited at low temperature (~ 300 ℃). The film delaminated during the post-coating High Pressure Rinsing (HPR), therefore the RF test of the cavity could not be performed at this round. A new deposition run will be carried out at a higher deposition temperature and increased film thickness, with the goal of improving adhesion and mechanical stability of the film.

Funding Agency:

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Thursday Poster Session - Board: THP32 / **206**

Activities on medium grain niobium at DESY

Author: Detlef Reschke[1]

Co-authors: Alexey Ermakov [1]; Andrea Muhs [1]; Christopher Bate [1]; Daniel Klinke [1]; Elena Ermakova [1]; Jan-Hendrik Thie [1]; Jens Iversen [1]; Julia Goedecke [1]; Karol Kasprzak [1]; Lea Steder [1]; Lennart Trelle [1]; Mateusz Wiencek [1]; Svenja Arnold [1]

[1] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Author: detlef.reschke@desy.de

Within the ITN (ILC Technology Network) activity led by KEK, the so-called "Medium Grain Niobium" is investigated with respect to its possible application for a large-scale SRF cavity production for the International Linear Collider ILC [1-3]. In the framework of the KEK-DESY collaboration, the niobium material for two 1.3 GHz single-cell cavities was supplied by KEK. After fabrication and initial surface treatment by electropolishing in industry, the cavities have been tested successfully at DESY with gradients above 40 MV/m. Subsequently, a heat treatment at medium temperatures around 350 ℃ (Mid-T heat treatment) in the DESY furnace was applied. The vertical test results of these treatments will be reported. In addition, the effect of UHV heat treatments on state-of-the-art fine grain niobium at temperatures between 800 ℃ and 1100 ℃ has been studied on samples with respect to grain growth, mechanical and thermal properties.

Footnotes:

[1] doi:10.18429/JACoW-SRF2021-MOPCAV004
[2] doi:10.18429/JACoW-SRF2021-MOPCAV012
[3] doi:10.18429/JACoW-SRF2023-WEIXA04

Funding Agency:

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Thursday Poster Session - Board: THP33 / **214**

Sideband excitation phenomena study in SRF vertical testing

Author: Enrico Cenni[1]

Co-authors: Angelo Bosotti [2]; Daniele Sertore [3]; Elisa Del Core [3]

[1] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

[2] *Istituto Nazionale di Fisica Nucleare, Laboratori Acceleratori e Superconduttività Applicata*

[3] *Istituto Nazionale di Fisica Nucleare*

Corresponding Author: enrico.cenni@cea.fr

Sideband excitations observed in superconducting radio-frequency (SRF) cavities during vertical tests are indicative of complex underlying phenomena that can impact cavity performance and their measurements. This work presents an analysis combining experimental data and numerical simulations to investigate the origins and contributions of multipactor and field emission to sideband generation. RF measurements and radiation monitoring were employed during vertical tests of several niobium cavities to characterize the temporal and spectral features of the side bands under varying field levels. Complementary particle tracking and electromagnetic simulations were performed to model electron trajectories, secondary emission, and RF power deposition in the cavity. This study provides new insight into the interplay between surface phenomena and RF field dynamics in SRF cavities and offers guidelines for improved interpretation of vertical test data and enhanced cavity processing strategies.

Thursday Poster Session - Board: THP34 / **171**

Characterizing and controlling recovery and recrystallization in Nb for improved SRF cavity performance

Author: Eric Taleff[1]

Co-authors: Sucharita Banerjee [1]; Thomas Bennett [2]; Shreyas Balachandran [3]; Santosh Chetri [3]; Trent Boritz [3]; Pashupati Dhakal [4]; Zack Thune [5]; Philip Eisenlohr [5]; Peter Lee [6]; Thomas Bieler [5]

[1] *The University of Texas at Austin*

[2] *Sandia National Laboratories*

[3] *Florida State University; National High Magnetic Field Laboratory*

[4] *Thomas Jefferson National Accelerator Facility*

[5] *Michigan State University*

[6] *National High Magnetic Field Laboratory*

Corresponding Author: taleff@utexas.edu

Crystal defects, such as dislocations and low-angle boundaries, provide sources of magnetic flux trapping in the Nb materials used for superconducting radio frequency (SRF) resonating cavities. Improving the performance of SRF cavities, as measured through the quality factor, requires reducing these defects. SRF cavity production involves deformation processing, such as rolling and forming, and strategic annealing heat treatments. The resulting microstructures can be recovered, recrystallized, or both. Because recovery leaves many defects that can trap flux, recrystallization should improve cavity performance. Thus, processing schedules that produce complete recrystallization without excessive grain growth need to be designed. Solutions to this problem require understanding physical metallurgy and differentiating between recovered and recrystallized regions of microstructure. Backscattered electron microscopy techniques are applied to this end. We demonstrate that the conditions required to produce fully recrystallized microstructures depend on Nb impurity content, suggesting that processing schedules may need to be adjusted by material heat or lot. We also demonstrate that processing can be used to control recrystallized grain growth to maintain mechanical strength in fully recrystallized materials. Forming cavities from cold-rolled Nb sheet material may provide strategic new routes to obtain microstructures that improve SRF cavity performance.

Funding Agency:

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Thursday Poster Session - Board: THP35 / **126**

Electrochemical impedance spectroscopy analysis of Nb electropolishing in HF solutions

Author: Eric Viklund[1]

Co-authors: David N. Seidman [2]; Davida Smith [3]; Sam Posen [3]; Tim Ring [3]; Vijay Chouhan [3]

[1] *High Energy Accelerator Research Organization*

[2] *Northwestern University*

[3] *Fermi National Accelerator Laboratory*

Corresponding Author: eric.viklund@kek.jp

Electropolishing (EP) is a critical process for achieving high quality factors (Q) and high accelerating gradients in superconducting radiofrequency (SRF) cavities. Despite its importance, the chemical mechanisms of EP remain unclear. Two primary models have been proposed: the viscous boundary layer theory, which attributes polishing to the formation of a viscous, HF-depleted boundary layer, and the compact film theory, which suggests polishing results from the formation of a solid, passivating film on the niobium's (Nb) surface. In this study, we investigate the EP mechanism using Electrochemical Impedance Spectroscopy (EIS) to probe the electrical properties of the Nb electrode during EP. By analyzing the distribution of relaxation times, we gain insights into the interfacial chemical processes occurring at the electrode's surface. Our EIS data supports the compact film model and indicates a two-step oxidation mechanism: initially, Nb is oxidized to NbO_2, followed by further oxidation to Nb_2O_5 as the applied voltage increases. The formation of Nb_2O_5 is correlated with a reduction in surface roughness, suggesting that effective EP occurs when a stable oxide layer develops on the surface. These findings provide new insights into the role of surface oxide formation in the EP of Nb for SRF applications.

Thursday Poster Session - Board: THP36 / **170**

RF measurements and performance tests at 4K of cryomodule 1 cavities for HELIAC

Author: Florian Dirk Dziuba[1]

Co-authors: Holger Podlech [2]; Julian List [3]; Maksym Miski-Oglu [1]; Stepan Yaramyshev [1]; Thorsten Kuerzeder [3]; Viktor Gettmann [1]; Winfried Barth [1]

[1] *GSI Helmholtz Centre for Heavy Ion Research*

[2] *Goethe University Frankfurt*

[3] *Helmholtz Institute Mainz*

Corresponding Author: f.dziuba@gsi.de

A new superconducting (sc) continuous-wave (cw) linear accelerator (linac) is currently being built at GSI to meet the future requirements in research on superheavy elements (SHE) synthesis and material science with a particular focus on fusion studies. The HElmholtz LInear Accelerator (HELIAC) will provide ion beams in the energy range from 3.5 MeV/u to 7.3 MeV/u with a mass-to-charge ratio (A/z) of up to 6. For acceleration, superconducting multi-cell crossbar-H-mode (CH) cavities operating at a resonance frequency of 217 MHz are used. Additionally, superconducting single-spoke (SSR) buncher cavities are employed for longitudinal beam matching within the CH sections. In 2023/2024, the first cryomodule, CM1, consisting of three CH cavities, one SSR, and two sc solenoids, was commissioned with beam at the GSI test stand. This paper presents RF measurements and performance tests of the cavities conducted during commissioning of CM1.

Thursday Poster Session - Board: THP37 / **200**

Interface studies of Nb-AlN-NbTiN multilayers grown by PEALD

Author: Isabel González Díaz-Palacio[1]

Co-authors: Alice Moros [2]; Alick Macpherson [2]; Andreas Stierle [3]; Daniel Turner [2]; David Reyes [4]; Heshmat Noei [5]; Lea Preece [1]; Marc Wenskat [1]; Miguel García Blanco [6]; Wolfgang Hillert [1]

[1] *Universität Hamburg*

[2] *European Organization for Nuclear Research*

[3] *Universität Hamburg; Deutsches Elektronen-Synchrotron DESY*

[4] *École Polytechnique Fédérale de Lausanne*

[5] *Deutsches Elektronen-Synchrotron DESY*

[6] *Deutsches Elektronen-Synchrotron DESY; Universität Hamburg*

Corresponding Author: isabel.gonzalez.diaz-palacio@uni-hamburg.de

Superconducting–Insulating–Superconducting (SIS) multilayers offer a promising approach to surpass the accelerating gradients and quality factors of standard bulk-Nb SRF cavities†. Plasma-enhanced atomic layer deposition (PEALD) stands out as a key technique for the next-generation thin-film-based SRF cavities, providing conformal coatings on highly structured, three-dimensional substrates without shadowing effects and with sub-nm thickness precision. This poster contributes to thin-film SRF R&D through dedicated material studies. The results presented correspond to Nb–AlN–NbTiN multilayers grown by PEALD, focusing on the S–I and I–S interfaces. Depth-resolved X-ray photoelectron spectroscopy (XPS) and cross-sectional energy-dispersive X-ray spectroscopy (EDX) are employed to assess the film stoichiometry and detect any interdiffusion or deposition residues. Side effects induced by high-temperature post-deposition annealing–required to obtain high-Tc NbTiN‡–are systematically investigated. Lastly, complementary studies on Superconducting–Superconducting (SS) Nb–NbTiN bilayers–grown without the AlN interlayer–underscore the crucial role of AlN as an effective diffusion barrier.

Footnotes:

†A. Gurevich, "Enhancement of rf breakdown field of superconductors by multilayer coating", Applied Physics Letters 88, 12511 (2006)

‡I. González Díaz-Palacio, M.Wenskat, G. K. Deyu, W. Hillert, R. H. Blick, and R. Zierold, "Thermal annealing of superconducting niobium titanium nitride thin films deposited by plasma-enhanced atomic layer deposition", Journal of Applied Physics 134, 035301 (2023)

Thursday Poster Session - Board: THP38 / **219**

Virtual cavity probe for the real-time identification of cavity burst-noise type in superconducting radio-frequency systems

Author: Jin Ma[1]

Co-author: Feng Qiu [1]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

Corresponding Author: majinying@impcas.ac.cn

Burst-noise events are primary trip sources at the China Accelerator Facility for superheavy Elements (CAFE2), characterized by a rapid burst noise in the cavity pick-up signal categorizable into three distinct types: flashover, electronic quench (E-quench), and partial E-quench. Herein, we design an algorithm identifying the burst-noise event types in real time to realize a real-time discrimination of the three types of burst-noise events. This algorithm is based on a virtual cavity probe constructed with the forward and reflected signals of the cavity and integrated into a field-programmable gate array (FPGA). Moreover, we introduce an innovative method for calibrating the transmission delay in channels. This FPGA-based low-level radio-frequency algorithm identifies the burst-noise event type in real time. Its effectiveness has been validated in the CAFE2 facility, offering valuable data support for future advancements in machine learning-based fault classification and dark-current characterization.

Thursday Poster Session - Board: THP39 / **147**

Fabrication of the prototype spoke cavity for the JAEA-ADS linac

Author: Jun Tamura[1]

Co-authors: Yasuhiro Kondo [1]; Bruce Yee-Rendon [1]; Shin-ichiro Meigo [1]; Fujio Maekawa [1]; Eiji Kako [2]; Kensei Umemori [2]; Hiroshi Sakai [2]; Takeshi Dohmae [2]

[1] *Japan Atomic Energy Agency*

[2] *High Energy Accelerator Research Organization*

Corresponding Author: jtamura@post.j-parc.jp

Japan Atomic Energy Agency (JAEA) has been proposing an accelerator-driven nuclear transmutation system (ADS) as a future nuclear system to efficiently reduce high-level radioactive waste generated at nuclear power plants. As the first step toward the full-scale CW proton linac for the JAEA-ADS, we are currently prototyping a low-beta (around 0.2) single-spoke cavity. Because there is no experience in manufacturing superconducting spoke cavities in Japan, prototyping and performance evaluation of the cavity are essential to ensure the feasibility of the JAEA-ADS. The actual cavity fabrication started in 2020, and the cavity assembly by electron-beam welding was finally completed in fiscal year 2024. The fabrication of the prototype spoke cavity is presented.

Thursday Poster Session - Board: THP40 / **199**

Measurement of low accelerating gradient in 1.3 GHz cavities at DESY

Author: Mateusz Wiencek[1]

Co-author: Karol Kasprzak [1]

[1] *Deutsches Elektronen-Synchrotron DESY*

Corresponding Author: mateusz.wiencek@desy.de

During last few years, an extensive effort for obtaining QvsEacc characteristic of SRF cavities at very low accelerating gradients have been conducted within labs around the world. In Accelerator Module Test Facility (AMTF) at DESY, several attempts of such measurement were performed, mainly focused on the comparison between widely used decay measurements technique and the standard vertical test. To ensure good quality of the signals at very low gradients, several hardware adaptations of the existing test - stand were introduced. In this paper, compliance between two measurement ideas is presented, as well as some cross-checking ideas, which could give an overview of the measurement quality at very low RF amplitudes.

Thursday Poster Session - Board: THP41 / **269**

Magnetic environment optimization in SRF testing at INFN-LASA

Author: Michele Bertucci[1]

Co-authors: Angelo Bosotti [2]; Bastiano Vitali [2]; Carlo Pagani [2]; Daniele Sertore [2]; Elisa Del Core [1]; Fabrizio Fiorina [2]; Laura Monaco [2]; Paolo Spruzzola [2]; Rocco Paparella [1]

[1] *Istituto Nazionale di Fisica Nucleare*

[2] *Istituto Nazionale di Fisica Nucleare, Laboratori Acceleratori e Superconduttività Applicata*

Corresponding Author: michele.bertucci@mi.infn.it

Minimizing residual magnetic fields during SRF cavity cooldown is essential for reducing surface resistance and improving the quality factor. At LASA-INFN, we implemented an active compensation system using Helmholtz-like coils in vertical test cryostats. The setup is optimized to reduce the average magnetic flux through the cavity surface by accounting for the spatial inhomogeneity of the residual field. Experimental studies on PIP-II prototype cavities confirm the critical role of magnetic field conditions during cooldown. Observations suggest that, if a quench occurs in the presence of such external fields, trapped flux can cause a lasting degradation of the quality factor.

Thursday Poster Session - Board: THP42 / **250**

Development of a cobot-assisted High Pressure Rinsing solution for SRF cavities

Author: Nicolas Gandolfo[1]

Co-authors: Bastien Delhaye [2]; David Longuevergne [1]; Lê My Vogt [2]; Mael Vannson [2]; Patricia Duchesne [2]; Sandry Wallon [2]

[1] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

[2] *Laboratoire de Physique des 2 Infinis Irène Joliot-Curie*

Corresponding Author: nicolas.gandolfo@ijclab.in2p3.fr

IJCLab has been contributing to several SRF accelerators in the world (SPIRAL2, ESS, PIP-II) and in particular was in charge of the design, surface preparation and qualification in vertical cryostat of low beta (i.e. complex 3D shape) resonators as Quarter-Wave Resonators (QWR) and Spoke Resonators. One of the main challenges of these complex geometries is the final surface cleaning by High Pressure Rinsing (HPR) to limit or in the best case suppress the Field Emission (FE) at nominal gradient. While standard HPR methods have effectively reduced FE, they could not eliminate it in these geometries. Since 2024, triggered and motivated by PIP-II prototyping phase, IJCLab is investing in COBOT technology (COllaborative roBOT) in an effort to improve HPR capabilities, leveraging the flexibility and precision of cobots to perform complex trajectories for optimal surface coverage. This paper will summarize the on-going R&D activities at IJCLab.

Thursday Poster Session - Board: THP43 / **149**

Strain gauge-based position monitoring of spaceframe-suspended SRF cavities

Author: Nina Ohm[1]

Co-authors: Adolfo Velez [2]; Fabian Pflocksch [1]; Felix Glöckner [1]; Jens Knobloch [3]; Kevin Schemmel [1]; Nora Wunderer [1]; Stefan Wiese [1]; Volker Dürr [1]

[1] *Helmholtz-Zentrum Berlin für Materialien und Energie*

[2] *TU Dortmund University*

[3] *University of Siegen*

Corresponding Author: nina.ohm-krafft@helmholtz-berlin.de

The VSR cavities, featuring protruding waveguides and HOM absorbers, are designed to be installed as part of the cold string in a spaceframe within a cryogenic vessel. Precise alignment of the cavities during installation and continuous position monitoring during operation are required to prevent damage of other cold string components such as bellows. To achieve this, strain gauges are installed on the rods suspending the cavity within the spaceframe, measuring the superimposed bending and normal forces. To validate this approach, assembly tests were conducted, comparing strain gauge measurements with laser tracker data. The results demonstrate that strain gauge-based monitoring enables continuous position tracking of the cavity. Operation within a vacuum vessel at low temperature still needs to be tested.

Thursday Poster Session - Board: THP44 / **275**

Hybrid Wire Laser Additive Manufacturing and CNC machining for advanced SRF cavity fabrication

Author: Oscar Azzolini[1]

[1] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro*

Corresponding Author: oscar.azzolini@lnl.infn.it

The fabrication of Superconducting Radio Frequency (SRF) cavities traditionally relies on forming and welding high-purity metal sheets, resulting in a local surface discontinuity that degrades the final SRF performance. In this work, we propose and explore a novel hybrid approach combining Wire Laser Additive Manufacturing (WLAM), with in situ CNC machining for the fabrication of monocell 1.3 GHz SRF cavity. This technique enables the layer-by-layer deposition of high-purity metals with precise dimensional control, while simultaneously integrating subtractive steps to maintain tolerances and surface quality crucial for RF performance. The hybrid WLAM and CNC machining stands as a candidate for next-generation SRF cavity production minimizing material waste, eliminating the need for electron beam welding, through the direct creation of complex geometries, and enhancing the surface finishing in the as-built condition. Results on stainless steel 1.3 GHz prototype are presented.

Thursday Poster Session - Board: THP45 / **60**

HOM antenna upgrades and refurbishment of TESLA cavities for the MESA ER-Mode

Author: Paul Plattner[1]

[1] *Johannes Gutenberg University Mainz*

Corresponding Author: pplattne@uni-mainz.de

The Mainz Energy-Recovering Superconducting Accelerator is currently under construction at the Institute for Nuclear Physics on the campus of the Johannes Gutenberg University Mainz. A future upgrade is planned for the multi-turn Energy Recovery (ER) mode, increasing the beam current from

1 mA to 10 mA in continuous wave at 1.3 GHz. Simulations have calculated an increased power deposition of 3 W in the Higher Order Modes (HOMs) of the TESLA cavities. The power, which is deposited by the passing electron beams through the cavity, is reduced in the cavity through the HOM dampers, but the power at the HOM antenna will increase up to 1 W. This will exceed the current limits and lead to a quench of the antenna. The quench limit could be increased by using an alternative superconducting material with a higher critical temperature than Niobium. Two candidates like Nb3Sn on Cu and NbTiN on Nb will be coated as a thin film on the antenna. Simulations have shown that the limit can be increased up to 1.1 W for NbTiN on Nb and 4.7 W for Nb_3Sn on Cu. Two TESLA cavities, from a cryomodule (CM) of the decommissioned ALICE(*) project, are refurbished in the clean room infrastructure of the Helmholtz Institute Mainz (HIM). The performance of the cavities will be tested in several configurations: after refurbishment, with the original antenna design, with coated antennas, and in the fully assembled cryomodule with an electron beam.

Footnotes:

(*)We would like to thank STFC Daresbury for their generous gift.

Funding Agency:

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Thursday Poster Session - Board: THP47 / **295**

Local magnetic field evolution in shielded SRF cavities during thermal cycling in a cryomodule-like configuration

Author: Mykhailo Zhovner[1]

Co-authors: Carl Svanberg [1]; Frank Marhauser [2]; Maja Olvegård [1]; Peter Salén [1]; Rocío Santiago Kern [1]

[1] *Uppsala University*

[2] *Belgian Nuclear Research Centre*

Corresponding Author: rocio.santiago_kern@physics.uu.se

At FREIA, Uppsala (Sweden), an investigation of the Magnetic Field (MF) evolution during cool-down / warm-up cycles of 352 MHz single spoke cavities for the MINERVA proton linac (Phase I of the MYRRHA project) has been carried out: bulk-Nb SRF cavities equipped each with a dedicated MINERVA cavity magnetic shield (MGS) made of CRYOPHY® material have been measured during their testing in the horizontal cryostat HNOSS.

The MF was monitored by multiple fluxgate sensors placed at various positions around the cavities during the cool-down and warm-up cycles. Note that HNOSS is equipped by design with a global mu-metal magnetic shield covering the inner walls of the cryostat vessel (at room temperature) to provide a reduction of the Earth's magnetic field to around 2 uT at lateral cavity test positions (otherwise higher). Together with the cavity-individual shields, this allowed to perform precise measurements of the remnant field.

Upon cool down, a change in the surrounding MF was observed due to the interplay of the Seebeck and Meissner effects, which directly correlates to the cavity's temperature profile.

The estimated influence of these MF dynamics on SRF cavity performance are discussed, while proposing optimized cool-down sequences aimed at minimizing trapped flux and enhancing the performance and reliability of SRF cavities for future accelerator applications.

Thursday Poster Session - Board: THP50 / **121**

Considerations on using SQUID metamaterials for tuning SRF cavities in accelerator applications

Author: Thomas Oseroff[1]

Co-author: Matthias Liepe [1]

[1] *Cornell University*

Corresponding Author: teo26@cornell.edu

Superconducting QUantum Interference Devices (SQUID)s are superconducting loops broken by one or more Josephson junctions and act as RLC circuits with a resonant frequency that can be tuned by an applied magnetic field. A microwave metamaterial can be created by positioning many of these SQUIDs in an array such that such that their spacing is much less than that of the microwave wavelength. In this work, the extent the resonant frequency of an accelerator cavity can be shifted for a given coupling with a SQUID metamaterial is obtained with two models. From this, it is considered if the cavity resonance shift is sufficient for weak enough couplings that such a cavity tuning scheme could be relevant for accelerator applications.

Thursday Poster Session - Board: THP51 / **122**

Attempt to include beam loading effects in finite element method RF simulations for B-cell cryomodules

Author: Thomas Oseroff[1]

Co-author: Matthias Liepe [1]

[1] *Cornell University*

Corresponding Author: teo26@cornell.edu

In this work a method to include the effects of beam loading in FEM solvers for electromagnetic problems, such as CST and HFSS, is considered. The method involves using transmission line models of a beam-loaded and beamless resonant cavity to determine an effective surface resistance and tuning angle for the beamless cavity to produce the same reflection as the beam-loaded case. The cavity, its coupler, and the relevant waveguide sections are then simulated with the desired surface resistance and shift from resonance. This allows for detailed understanding of the fields in regions of interest, such as transformers and RF windows, as a function of relevant parameters, such as beam current, cavity voltage, and tuning angle.

Thursday Poster Session - Board: THP52 / **120**

The design and test of 648 MHz 6-cell elliptical cavity for CSNS-II

Author: Wenzhong Zhou[1]

Co-authors: Xiaolei Wu [2]; MengXu Fan [1]; Qiang Chen [1]; baiqi liu [1]; Feisi He [1]; Rui Ge [1]; Jin Dai [1]; Cong Zhang [1]; song jin [1]; Bo Li [1]

[1] *Institute of High Energy Physics*

[2] *Dongguan Neutron Science Center*

Corresponding Author: zhouwz@ihep.ac.cn

Since the second half of 2022, the design of the CSNS-II elliptical cavities was completed and their manufacturing was initiated. After nearly three years of research, we have successfully developed three prototype elliptical cavities. Vertical tests demonstrated a maximum gradient of 25.7 MV/m, significantly surpassing the operational requirement of 14 MV/m. This achievement has laid a solid foundation for the construction of CSNS-II.

Thursday Poster Session - Board: THP53 / **105**

Development of 1.3 GHz 3-cell superconducting cavities for high current application

Author: Xiaowei Wu[1]

Co-authors: Dong Wang [2]; Haixiao Deng [2]; Jinfang Chen [2]; Meng Zhang [2]; ShenJie Zhao [2]; Xuan Huang [3]; Yue Zong [2]; Zheng Wang [3]

[1] *Zhangjiang Laboratory*

[2] *Shanghai Advanced Research Institute*

[3] *Shanghai Institute of Applied Physics*

Corresponding Author: wuxw@zjlab.ac.cn

1.3 GHz 3-cell superconducting cavities were proposed for the injector of the high-brightness free electron laser based on energy recovery linac scheme. The average beam current is 10 mA and injector energy is 10 MeV. The beam tube of the cavity is enlarged to damp higher-order modes (HOMs) and to keep beam stability. Three cavities have been fabricated. An intrinsic quality factor of 2.0×10^{10} at 12.0 MV/m and a maximum accelerating gradient of 26.0 MV/m were achieved in the vertical test of the first bare cavity. Design, fabrication, surface treatment, and rf test results will be presented in this paper.

Thursday Poster Session - Board: THP54 / **282**

Preliminary physics design of 1.3 GHz superconducting electron gun

Author: XiongHao Yuan[1]

Co-authors: Haixiao Deng [1]; Houjun Qian [2]; Guan Shu [2]; Jinfang Chen [3]; Hongtao Hou [3]; xiaoyun pu [4]

[1] *Shanghai Institute of Applied Physics*

[2] *Shanghai Zhangjiang Laboratory*

[3] *Shanghai Advanced Research Institute*

[4] *Shanghai Advanced Research Institute, Chinese Academy of Sciences*

Corresponding Author: 550737488@qq.com

High gradient CW electron guns are essential for high-repetition-rate, high-brightness electron beams, key to advanced light sources and other applications. Compared to DC guns and normal conducting VHF guns, SRF guns are considered the next-generation solution for further boosting CW gun acceleration capabilities and electron source brightness. This paper presents the initial physics design of an SRF gun aiming for a 30 MV/m cathode field. It covers RF design optimizations, beam dynamics simulations, and frequency stability analyses. Results demonstrate the feasibility of the SRF gun design, and paves the way for the next phase of engineering development.

Funding Agency:

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Thursday Poster Session - Board: THP55 / **251**

The influence of rolling direction and surface pinning of deformed grain boundaries during recrystallization in high-RRR niobium sheet

Author: Zackery Thune[1]

Co-author: Thomas Bieler [1]

[1] *Michigan State University*

Corresponding Author: thunezac@msu.edu

The ability to accurately and consistently quantify the recrystallized (Rx) microstructure of heat-treated high-purity Nb used in superconducting radiofrequency (SRF) applications is critical for the improvement of material processing and cavity production. The production of SRF cavity half-cells by deep-drawing Nb sheets into the half-cell geometry results in different stain paths in different locations of the cavity (which includes prior rolling history). Cavity production typically removes the damaged surface layer followed by a vacuum anneal at 800℃ for 3-hours. Dislocation substructures that develop during the anneal are known to be sources of magnetic flux trapping, and higher temperature anneals between 900 and 1000℃ have shown cavity performance improvement through the reduction of these defects. As the microstructure within each lot of Nb varies, it is possible that rolling coupons in different directions could identify differences in Rx response with respect to the rolling direction and provide guidance for the optimal anneal for a given lot. The significance of the strain path effect is exaggerated on the surface due to pinning of deformed grain boundaries during the anneal. Removal of surface grains reveals a more homogeneous Rx with larger grain sizes. Hence, it is critical for the SRF community to understand where measurements are taken (surface vs. interior) to accurately quantify the extent of Rx present in the material.

Funding Agency:

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Thursday Poster Session - Board: THP56 / **253**

The effects of strain path and strain magnitude on the uniformity of recrystallization in high-RRR niobium 1.3 GHz half-cells

Author: Zackery Thune[1]

Co-authors: Shreyas Balachandran [2]; Thomas Bieler [1]

[1] *Michigan State University*

[2] *Florida State University*

Corresponding Author: thunezac@msu.edu

The consistent production of high-RRR Nb cavities for superconducting radiofrequency applications is critical to advancements in accelerator performance and technology. Despite standard guidelines for material and cavity production, the properties and performance of these cavities can vary significantly. Improvements in cavity performance due to better flux expulsion are observed after heat treatment temperatures in the range of 900-1000℃. This can be attributed to more recrystallization (Rx) and grain growth that removes geometrically necessary dislocations (GNDs) that act as magnetic flux pinning centers. Recent work has shown that the observed Rx fraction via electron backscatter diffraction (EBSD) analysis of GNDs in cold-rolled high-RRR Nb to be strain path dependent. A high-RRR deep-drawn Nb half-cell was sliced with section edges aligned 0°, 45°, and 90° from the final rolling direction of the Nb sheets. The effects of heating rate (5 and 250℃/min), annealing temperature (800 and 900℃), strain path, and strain magnitude on the Rx fraction and uniformity were quantitatively assessed in samples from the iris, equator, and a lesser-strained region in between. The insights gained from these microstructural observations can guide novel heat treatment strategies that enable consistent higher-performance cavity production.

Funding Agency:

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Thursday Poster Session - Board: THP57 / **287**

High intensity proton cryomodule parasitic radiation analysis

Author: Guillaume Devanz[1]

Co-authors: Cecilia Maiano [2]; Enrico Cenni [3]; Olivier Piquet [4]

[1] *Commissariat à l'Energie Atomique*

[2] *European Spallation Source*

[3] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

[4] *CEA Paris-Saclay*

Corresponding Author: guillaume.devanz@cea.fr

Experimental evidence of parasitic radiation originating from cavity field emission or beam losses and interacting with cryomodule diagnostics has been collected.
We focus on the case of spurious triggering of power coupler interlock system which is based on the light detection of arcs and its transmission in optical fibers. Scenario of radiation interaction are modeled using Geant4, aiming at reproducing several experimental observations, in the case of ESS high beta cryomodules and investigate possible mitigation techniques.

Thursday Poster Session - Board: THP58 / **329**

Low beta cavity production based on a novel procedure at IMP

Author: Zhijun Wang[1]

Co-authors: Feng Bai [2]; Shichun Huang [2]; TIANCAI JIANG [2]; Yuan He [1]; shengxue zhang [2]

[1] *Institute of Modern Physics, Chinese Academy of Sciences*

[2] *Institute of Modern Physics*

Corresponding Author: wangzj@impcas.ac.cn

Three superconducting linear accelerators are under construction at the Institute of Modern Physics (IMP) of the Chinese Academy of Sciences (CAS). 96 superconducting radio frequency (SRF) cavities housed in 17 cryomodules were fabricated, preparation and installed in the accelerator tunnel in 14 months. The cold test of the SRF cavity and cryomodule is skipped due to our excellent full-process quality control. The mass production of SRF cavity shows good performance, a higher accelerating gradient than the operation specification is achieved. In this paper, an overview of the cavity design, production fabrication, string and cryomodule assembly, efforts for SRF cavity performance recovery and operation status are introduced.

Thursday Poster Session - Board: THP59 / **134**

PIP-II LB650 cryomodules test bench at CEA

Author: Hassen Jenhani[1]

Co-authors: ARCAMBAL Christian [2]; BERTRAND Quentin [2]; BOUNOU Mehdi [2]; BREDY Philippe [2]; Claire Simon [3]; Guillaume Devanz [3]; HASSANE Florian [2]; Luc Maurice [3]; MAILLERET Charles [2]; Nicolas Bazin [3]; Olivier Piquet [2]; SAHUQUET Patrick [2]

[1] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

[2] *CEA Paris-Saclay*

[3] *Commissariat à l'Energie Atomique*

Corresponding Author: hassen.jenhani@cea.fr

The Proton Improvement Plan - II (PIP-II) project at Fermi National Accelerator Laboratory (Fermilab) is the first U.S. accelerator initiative to include major in-kind contributions (IKC) from international partners. As part of the French contribution, the French Alternative Energies and Atomic Energy Commission (CEA) will deliver ten 650 MHz low-beta (LB650) cryomodules. These cryomodules incorporate superconducting cavities provided by INFN-LASA (Italy), Fermilab (USA), and DAE-VECC (India), as well as RF power couplers and tuning systems from Fermilab. The scope of work carried out by CEA includes the design, manufacturing, integration, and performance testing of the cryomodules. This paper focuses on recent progress related to the Site Acceptance Tests (SAT) for the main equipment of cryogenic and RF systems and the preparation of the test stand for the LB650 cryomodules. It highlights the ongoing efforts and progress made in preparing the infrastructure, as well as the steps being taken to ensure readiness for the upcoming cryogenic and high-power RF testing phases of the LB650 cryomodules.

Thursday Poster Session - Board: THP60 / **210**

Mitigating residual magnetization in coldmass components via superconducting focusing lenses

Author: Jacopo Bernardini[1]

Co-authors: Donato Passarelli [1]; Mattia Parise [1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: jbernard@fnal.gov

Residual magnetization of ferromagnetic coldmass components located near superconducting RF (SRF) cavities poses a significant threat to cavity performance, especially when a magnetic source, such as a focusing lens, is in close proximity. Previous work evaluated several passive mitigation techniques, including the use of local magnetic shields, and quantified both the residual fields induced by the focusing lenses and their detrimental impact on SRF cavity performance. Building on those findings, this paper presents the development and preliminary validation of an active demagnetization procedure to mitigate such effects. Using a dedicated magnet test stand equipped with a superconducting magnet, comprising a solenoid and four dipole correctors, and multiple fluxgate sensors, we explored demagnetization cycles with varying amplitudes and polarities. Initial results demonstrate a measurable reduction in remanent magnetic fields after the application of bidirectional ramp cycles. These findings pave the way for implementing robust in-situ demagnetization procedures as a complementary approach to passive magnetic hygiene and material selection strategies.

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Thursday Poster Session - Board: THP61 / **118**

Assembly of the LIPAc SRF LINAC cryomodule

Author: Janic Chambrillon[1]

Co-authors: Fabio Cismondi [1]; Francesco Scantamburlo [1]; Guillaume Devanz [2]; Jean-Pierre Adam [3]; Kai Masuda [4]; Kazuo Hasegawa [4]; Keitaro Kondo [4]; Nicolas Bazin [2]; Nicolas Chauvin [2]; Takashi Ebisawa [4]; Tomoya Akagi [4]

[1] *Fusion for Energy*

[2] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

[3] *Fusion for Energy; Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

[4] *National Institutes for Quantum Science and Technology*

Corresponding Author: janic.chambrillon@f4e.europa.eu

In complement to the development activities for fusion reactors (JT-60SA & ITER), Fusion for Energy contributes to the R&D for material characterisation facilities. The LIPAc, technical demonstrator for the production and acceleration of a D+ beam, will be used for neutron production by nuclear stripping reaction on a liquid Li target. Since its first beam in 2014, the LIPAc construction and commissioning continues and will be concluded with the cryomodule installation aiming for beam validation at nominal power. The cryomodule assembly, started in March 2019, was paused for two and half years, devoted to improve the pumping, repair, cold tests and high pressure rinse the solenoids. In August 2022, the cleanroom activities resumed with the cavity/coupler assembly but had to be paused again to fix a leaking bellows on a solenoid. In September 2024, the beam line left the cleanroom to start the cold mass assembly phase which was concluded in January 2025 with the cold mass insertion. In March 2025, the cryomodule was transported to the accelerator vault for the last assembly steps before its integration. The team is working on the connection of the super-conducting solenoids. The final leak tests of the cryomodule, conclusion of its assembly, are expected in the second half of 2025. This paper presents the technical challenges encountered and their solutions, highlighting continuous progress in overcoming complex integration issues across a synergic international collaboration.

Thursday Poster Session - Board: THP62 / **177**

Improved calorimetric cavity measurement techniques for the HB650 prototype cryomodule for PIP-II

Author: Jeremiah Holzbauer[1]

Co-authors: Adam Wixson [1]; Joseph Ozelis [1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: jeremiah@fnal.gov

Measuring cavity quality factors in a cryomodule requires calorimetric techniques because of the heavy input overcoupling. This involves using physical parameters of the cryogenic system such as mass flow, bath pressure, helium liquid level to estimate dynamic heat load of SRF cavities, often calibrated with heaters. The main challenges of these techniques are reducing sources of variation and error in the system to below the precision level required for the low dynamic heat levels added by the cavities and identifying and incorporating all of the important parameters into the analysis. For testing of the prototype HB650 cryomodule for PIP-II, we've developed a completely data-driven fitting technique that significantly reduces the error of the resulting qualify factor measurements which reducing the overall length of the measurement. This technique with example analyses and error analysis will be presented.

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Thursday Poster Session - Board: THP63 / **205**

RF in situ heating of a single and nine cell 1.3 GHz cavity

Author: Julia Goedecke[1]

Co-authors: Thorsten Büttner [1]; Karol Kasprzak [1]; Giovanni Marconato [2]; Detlef Reschke [1]; Lea Steder [1]; Mateusz Wiencek [1]; Alexey Sulimov [1]; Hans Weise [1]

[1] *Deutsches Elektronen-Synchrotron DESY*

[2] *Università degli Studi di Padova*

Corresponding Author: julia.goedecke@desy.de

High acceleration gradients Eacc and high quality factors Q0 can be achieved by heat treatments of the cavity [1]. However, the heating processes are carried out in furnaces where the cavity is forcibly exposed to air afterwards, which can lead to contamination. For moderate temperatures (T < 350 ℃), this issue could be overcome by in-situ heating. A few studies on in-situ heating have already been published, showing promising results [2]. But, the heating was achieved using heating strips, which are not applicable in an accelerator cryomodule. By applying a radio frequency electromagnetic field at RT to the cavity (here called RF-heating), the cavity can be heated under UHV conditions without being exposed to air. Furthermore, this setup could be implemented in the module, which is beneficial for accelerators that don't have the option of gas processing. A first study reporting on RF heating, still in its early stages, was published recently [3]. In the work presented here, we will further investigate RF heating and explain the experimental setup. In addition, first heating results for a 1.3 GHz nine-cell and a single-cell cavity will be presented, whereby temperatures in the mid-T range (approx. 240 ℃) have already been achieved for a single cell with the current setup.

Footnotes:

[1] L. Steder et al.,2024 , https://doi.org/10.48550/arXiv.2407.12570
[2] S. Posen et al.,2020 , Phys. Rev. Applied 13, 014024
[3] H.-W. Glock et al.,2024, https://doi.org/10.48550/arXiv.2412.13628

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Thursday Poster Session - Board: THP64 / **185**

The development and application of expansion joints

Author: kai huang[1]

[1] *FLEXTAI LTD*

Corresponding Author: kai.huang@flextai.com

FLEXTAI LTD is located in Shenyang Economic and Technological Development Zone, Liaoning Province, China. It is the first Sino-foreign joint venture in China specializing in the production of metal corrugated pipe series products. The company mainly engages in the design, development and manufacture of metal bellows, metal bellows expansion joints, metal hoses, precision bellows and pipeline systems. Relying on advanced technology and equipment, the company has become one of the important manufacturers of metal bellows expansion joints in both domestic and international markets. The various types of metal bellows produced by the company have been widely used in industries such as aviation and aerospace, power (thermal power, nuclear power, hydropower, etc.), steam turbines, gas turbines, ultra-high voltage power transmission and transformation, instruments and meters, metallurgy, petrochemicals, oil storage and transportation, urban centralized heating, light industry, electronics, and pharmaceuticals.

Thursday Poster Session - Board: THP65 / **230**

Utilization of remote monitoring tools in the long-term operation of the superconducting linac at RIKEN

Author: Kenta Kaneko[1]

Co-author: Akito Uchiyama [2]

[1] *SHI Accelrator Service Ltd.*
[2] *RIKEN Nishina Center*

Corresponding Author: kenta.kaneko.zu@a.riken.jp

Compared to normal-conducting accelerators, superconducting linacs require a dramatically larger number of parameters to be monitored, including not only RF power and beam-related signals, but also cryogenic conditions such as helium tank pressure, vacuum levels, and cavity temperatures. This increased complexity demands robust and flexible monitoring systems, especially during extended operation over several consecutive months.

At RIKEN superconducting heavy-ion linac (SRILAC), EPICS (Experimental Physics and Industrial Control System) serves as the main control framework, providing standard GUI tools such as control panels and archive viewers. However, as the scale and duration of operation have grown, the need for more accessible and responsive monitoring solutions has become apparent.

To meet this need, we have developed web-based applications using Ajax, React, and D3.js. These tools provide real-time access to trend graphs, Machine Protection System (MPS) alarm status, and control screen streaming—all through a standard web browser. This setup enables accelerator staff to monitor system conditions not only from the control room, but also from offices, labs, or even from home. We report on how these tools have proven useful in maintaining effective monitoring during the long-term operation of SRILAC.

Thursday Poster Session - Board: THP66 / **252**

Mock-up waveguide loop development toward a half-meter scale traveling-wave SRF cavity

Author: Fumio Furuta[1]

Co-authors: Kellen McGee [1]; Sergey Kazakov [1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: kem11235@fnal.gov

Traveling-Wave (TW) technology can push the accelerator field gradient of niobium SRF cavity to 70 MV/m or higher beyond the fundamental limit of 50~60 MV/m in Standing-Wave regime. The success of TW resonance excitation in a proof-of-principle 3-cell SRF cavity in 2 K liquid helium encouraged to advance TW technologies necessary more for future accelerator-scale one. Fermilab has proposed a preliminary RF design of a half-meter scale cavity by considering the physical dimensions of existing SRF facilities and the lessons learned from the 3-cell. It consists of a 7-cell structure and a power feedback waveguide (WG) loop with new TW excitation and control schemes such as, double directional coupler and two WG tuners. Mock-up waveguide loop development was launched under Fermilab LDRD program to demonstrate those new RF schemes at a room temperature. Fabrication drawings of a mock-up loop were completed. More details and plans of the development will be presented.

Thursday Poster Session - Board: THP67 / **208**

Feature of NC25 material and impact on flux trapping when used them for SRF cavity assembly

Author: Kenji Saito[1]

Co-authors: Wei Chang [1]; Chris Compton [1]; Spencer Combs [1]; Kyle Elliott [1]; Walter Hartung [1]; Sang-hoon Kim [1]; Taro Konomi [1]; Laura Popielarski [1]; Yuting Wu [1]; Ting Xu [1]

[1] *Facility for Rare Isotope Beams*

Corresponding Author: saito@frib.msu.edu

FRIB has developed a high Q 0.53HWRs within a DOE R&D program titled Development of Transformative Preparation Methods to Push up High Q&G Performance of FRIB Spare HWR Cryomodule Cavities. In this study, we found that flux trapping produces 80 % of the residual surface resistance (Rres). The main contribution is that from thermoelectric current produced by Seebeck effect (Dynamical magnetic contamination) at the dissimilar metal join nearby cavity. Other contributions are DC magnetic contaminations: insufficient earth magnetic field and magnetic contamination from the magnetized components used nearby cavity. Uniform cool-down reduces the dynamic magnetic flux, the ambient field is reduced to ~ 6 mG, and the resultant Rres is ~ 3 nW. Active field cancellation

reduces the DC ambient field more to 3 mG and decreases Rres to ~ 2 nW. FRIB 0.53HWR is operated at 322 MHz at 2 K. RBCS is ~ 0.5 nW, and Rres dominates to Qo. If reduce the Rres less than 0.5 nW, Qo could reach ~1x10^11. To enhance Qo, we tried to use NC25 bolts and nuts instead SUS ones, which are perfectly none magnetized material even after work unlike SUS. We investigated the impact on the cavity performance. In this paper, report about this result.

Footnotes:

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† Retired MSU/FRIB and moved to Aoi Kogyo Co. Ltd.,
email address: k-saito@aoi-k.co.jp or saito@frib.msu.edu

Thursday Poster Session - Board: THP68 / **241**

Preliminary cryogenic design for superconducting deflecting cavities for E2.0

Author: Marco Modica[1]

Co-authors: Alessandro Fabris [1]; Emanuel Karantzoulis [1]; Koryun Manukyan [1]; Nuaman Shafqat [1]; Sara Dastan [1]; Simone Di Mitri [1]; Stefano Cleva [1]

[1] *Elettra-Sincrotrone Trieste S.C.p.A.*

Corresponding Author: marco.modica@elettra.eu

Picosecond-long X-ray pulses of moderate intensity and high repetition rate are highly sought after by the light source community, especially for time-resolved fine spectroscopic analysis of matter in the linear response regime. We investigate the upgrade of the Elettra 2.0 diffraction-limited storage ring light source to radiofrequency transverse deflecting superconducting cavities generating a steady-state vertical deflection of selected electron bunches. In this paper, a preliminary design of the cryomodule of the deflecting superconducting cavities is reported, both static and dynamic thermal loads are calculated using an analytical approach. The dynamic loads are calculated assuming both bulk Nb and Nb3Sn thin film cavities. The two different solutions involve different cryogenic plants, which will be reported.

Thursday Poster Session - Board: THP69 / **297**

Construction of the LB650 pre-production cryomodule for the PIP-II linear accelerator

Author: Nicolas Bazin[1]

Co-authors: Claire Simon [1]; Guillaume Devanz [1]; Hassen Jenhani [2]; Robin Cubizolles [3]; Stéphane Berry [3]

[1] *Commissariat à l'Energie Atomique*

[2] *CEA Paris-Saclay*

[3] *Commissariat à l'Énergie Atomique et aux Énergies Alternatives*

Corresponding Author: nicolas.bazin@cea.fr

The Proton Improvement Plan II (PIP-II) that will be installed at Fermilab is the first U.S. accelerator project that will have significant contributions from international partners. CEA joined the international collaboration in 2018 and will deliver 10 low-beta cryomodules as In-Kind Contributions to the PIP-II project, with cavities supplied by LASA-INFN (Italy) and VECC-DAE (India), and power couplers and tuning systems supplied by Fermilab. This paper will detail the activities at CEA on the construction of the LB650 pre-production cryomodule.

Thursday Poster Session - Board: THP71 / **150**

When plastic meets particle physics: developing & characterising 3D-printed vacuum vessels for helium leak testing at high stakes and low pressures

Authors: Graeme Burt[1]; Luke Farley[1]; Niklas Templeton[2]; Oliver Poynton[2]; Stuart Wilde[3]

[1] *Lancaster University*

[2] *Science and Technology Facilities Council*

[3] *Daresbury Laboratory*

Corresponding Author: oliver.poynton@stfc.ac.uk

STFC Daresbury Laboratory recently completed the build of a Radio Frequency Dipole (RFD) crab cavity cryomodule prototype for the Super Proton Synchrotron (SPS), and the Double Quarter Wave (DQW) series build is currently underway. A key challenge was the leak testing of 34 unique weld configurations which could not be tested in the typical evacuation method.

A suite of 3D printed weld test tools mixing aluminium and SLA 3D printing were developed and reported on, with major savings to time and cost and improved quality of leak testing tooling, whilst maintaining a baseline leak rate of >5.00e-12 mbar L/s at, or below, 1.00e-3 mbar*.

STFC has continued to develop this promising technique expanding to fully 3D printed geometries and structures. This paper will report on the development and results from fully 3D printed vacuum chambers, its cleanroom compatibility, and general vacuum characteristics.

Footnotes:

*"Development of SLA 3D printed volumes for leak testing of LHC Hi-Lumi cryomodules at STFC"
February 2025Vacuum 234(5):114090
DOI: 10.1016/j.vacuum.2025.114090

Thursday Poster Session - Board: THP72 / **132**

New cleanroom nitrogen purge system to be used for superconducting radio frequency cavity string build at STFC

Author: Stuart Wilde[1]

Co-authors: Keith Middleman [1]; Oliver Poynton [1]

[1] *Daresbury Laboratory*

Corresponding Author: stuart.wilde@stfc.ac.uk

STFC has built new infrastructure to enable particulate control whilst building superconducting radio frequency cavity string and beam line assemblies that can be used in high beta cryomodule applications. The new facility includes an ISO4 cleanroom, low particulate high pressure rinse, and most recently, a nitrogen purge system that can allow varying and controlled purge of nitrogen through vacuum vessels as they are built. The nitrogen purge ensures that particulate ingress onto sensitive surfaces, such as within high beta RF cavities, is minimised. This paper describes the new purge system, its capabilities, and results from thorough validation testing to ensure that it operates within the required specification.

Thursday Poster Session - Board: THP73 / **238**

String assembly for the first HELIAC cryomodule

Author: Thorsten Kuerzeder[1]

Co-authors: Christoph Burandt [2]; Florian Dirk Dziuba [2]; Julian List [1]; Maksym Miski-Oglu [2]; Stepan Yaramyshev [2]; Szymon Kowina [2]; Viktor Gettmann [2]; Winfried Barth [2]

[1] *Helmholtz Institute Mainz*

[2] *GSI Helmholtz Centre for Heavy Ion Research*

Corresponding Author: t.kuerzeder@gsi.de

The Helmholtz Linear Accelerator HELIAC is a superconducting (sc) continuous wave linear accelerator for heavy ions currently under development at GSI in Darmstadt. However, single cavity tests and the majority of cleanroom activities took and still take place at the designated facilities of the Helmholtz Institute Mainz (HIM). Each of the sc cryomodules of the HELIAC houses 3 crossbar acceleration cavities, a sc rebuncher cavity and 2 sc solenoid lenses. Such a string is about 5 m long and has a mass of roughly 600 kg. Therefore for the cleanroom assembly in ISO-class 4 a heavy duty rail and girder system was used. The first cryomodule was successfully tested in Dezember 2023. We will report on the cleaning procedures and assembly steps as well as the finale integration into cryomodule at HIM.

Thursday Poster Session - Board: THP75 / **261**

Expansion of the line-up of high capacity 4 K GM-JT cryocooler system

Author: Yuki Iino[1]

Co-author: Taiki Ikeda [1]

[1] *Sumitomo Heavy Industries (Japan)*

Corresponding Author: yuki.iino@shi-g.com

Recent advancements in Nb_3Sn cavity development have enabled the design of SRF accelerators utilizing compact mechanical cryocoolers instead of helium liquefiers, simplifying system architecture and reducing costs. In this background, our company has released a high-efficiency, high-capacity 4 K GM-JT (Gifford-McMahon-Joule-Thomson) cryocooler system with 10 W-class cooling capacity at 4.2 K. This system provides higher efficiency and superior cooling performance in comparison to GM or PT (Pulse-Tube) cryocooler systems. So, it contributes to reducing power consumption,

installation footprint, and maintenance costs for customer systems. To further promote the adoption of GM-JT cryocooler systems, ongoing development efforts focus on expanding low-vibration line-up, shortening cooldown times, and broadening operational temperature ranges. The progress of these developments will be presented at this conference.

Thursday Poster Session - Board: THP76 / **277**

The RF power source systems of CSNS-II Linac RF superconducting cavities

Author: Zhencheng Mu[1]

Co-authors: Hexin Wang [1]; Hui Zhang [1]; Linyan Rong [1]; Maliang Wan [1]; Zhexin Xie [1]; bo wang [1]

[1] *Institute of High Energy Physics*

Corresponding Author: muzc@ihep.ac.cn

The CSNS-II superconducting Linac accelerator includes 20 sets of 324 MHz superconducting spoke cavities and 24 sets of 648 MHz superconducting ellipsoidal cavities. The 324 MHz/300 kW solid-state power source supplies RF power to superconducting spoke cavity, while the 648 MHz/1.2 MW klystron power source supplies RF power to superconducting ellipsoid cavity. The 324 MHz/300 kW solid-state power source uses GaN amplifier tubes and is composed of two cabinets. The long-pulse solid-state modulator supplies pulsed high voltage to the 648 MHz/1.2 MW klystron. The RF pulse width is 1.2 ms, the repetition rate is 50 Hz.

Thursday Poster Session - Board: THP77 / **184**

Development of 1.5 GHz harmonic superconducting cavity and cryomodule

Author: Zheng Mi[1]

Co-authors: Baiqi Liu [2]; Feisi He [2]; Hongjuan ZHENG [2]; Jiyuan Zhai [2]; Rui Ge [2]; Weimin Pan [1]; Xiaochen Yang [3]; song jin [2]

[1] *Chinese Academy of Sciences*

[2] *Institute of High Energy Physics*

[3] *University of Science and Technology of China*

Corresponding Author: mizh@ihep.ac.cn

The Institute of High Energy Physics (IHEP) developed the 1.5 GHz high -order harmonic cavity system for the Hefei Advanced Light Facility (HALF) project. This paper primarily introduces the design and development of the 1.5 GHz high-order harmonic superconducting cavity and cryomodule. The structure of the harmonic cavity has been simplified, and an integral welding method for the cavity with helium vessel has been adopted to enhance operational reliability. This not only reduces the complexity of the cavity but also minimizes potential failure points, thereby significantly improving the stability and performance of the 1.5 GHz high-order harmonic cavity system during operation. The design and development strategies presented here provide valuable references for similar high-frequency superconducting cavity projects in the future.

Thursday Poster Session - Board: THP78 / **179**

Preliminary design of continuous wave low-level RF systems for S3FEL

Author: Zhiyuan Zhang[1]

Co-authors: Jinfu Zhu [1]; Hongli Ding [2]; Qiaoye Ran [1]; Weiqing Zhang [2]

[1] *Institute of Advanced Science Facilities, Shenzhen*

[2] *Dalian Institute of Chemical Physics*

Corresponding Author: zhangzhiyuan@mail.iasf.ac.cn

In the Shenzhen Superconducting Soft X-ray Free Electron Laser (S3FEL), Continuous Wave (CW) Low-Level Radio Frequency (LLRF) systems perform critical functions including adjusting the power coupling of accelerator cavities, regulating the amplitude and phase of the RF field, and maintaining the resonance frequency and phase of the cavities. These functions are essential to ensure the electron beam operates at the accelerating phase. Within S3FEL, each superconducting cavity is driven by a solid-state amplifier (SSA), with each SSA paired with a dedicated LLRF system. Based on the distinct acceleration cavities employed, the CW LLRF systems for S3FEL are categorized into four types: 1. Primary accelerator LLRF systems (superconducting, 1.3 GHz; quantity: 168), 2. Harmonic cavity LLRF systems (superconducting, 3.9 GHz; quantity: 16), 3. VHF electron gun LLRF systems (room temperature, 216 MHz; quantity: 4), 4. Buncher LLRF systems (room temperature, 1.3 GHz; quantity: 2). These four LLRF system categories exhibit differing requirements for RF field and acceleration cavity control. This report presents the preliminary design schemes for these four types of CW LLRF systems.

Thursday Poster Session - Board: THP79 / **215**

CFD simulation of micron-scale dust particle transport and deposition in superconducting accelerator vacuum lines

Author: Zhizhen Luo[1]

Co-authors: Jiyuan Zhai [1]; Feisi He [1]; Baiqi Liu [1]

[1] *Institute of High Energy Physics*

Corresponding Author: zzluo@ihep.ac.cn

During vacuum commissioning and operation of large superconducting accelerators, gas flow may induce the dust particle within pipelines, causing intolerable particulate contamination in superconducting radio frequency (SRF) cavities. Investigating the transport behavior of microscale solid particles within accelerator pipelines is critical for understanding and solving particulate contamination problems in superconducting accelerators.

Computational fluid dynamics (CFD) methods with proper conditions can accurately predict particle behavior in gas flows. We developed our own OpenFOAM solver and case setup to systematically investigate the transport and deposition behavior of micron- and submicron-scale particles in long straight pipelines. Initially, we simulated gas flows in a sufficiently long straight circular pipe with different inlet velocity for an extended duration to obtain fully developed velocity profiles. These velocity profile were then applied as boundary conditions at both the inlet and outlet to maintain fully developed flow conditions within the computational domain during the simulation. Building upon this foundation, we thoroughly investigated the influence of three key operational parameters —gas flow rate, pressure, and particle size on the behavior of the test particle in pipelines. These findings can offer valuable insights and references for controlling particle contamination issues in SRF cavities.

Funding Agency:

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Thursday Poster Session - Board: THP80 / **133**

Searching for axions: a new SRF cavity-based programme at CERN

Author: Lee Millar[1]

Co-authors: Alick Macpherson [1]; Alexej Grudiev [1]; Natalia Koss [1]; Diego Barrientos [1]; Leonardo Balocchi [1]; Sergio Calatroni [1]; Sebastian Ellis [2]; Torsten Koettig [1]; Sofia Vallecorsa [1]

[1] *European Organization for Nuclear Research*

[2] *University of Geneva*

Corresponding Author: lee.millar@cern.ch

As part of the Quantum Technology Initiative (QTI) at CERN, a programme to develop a novel SRF cavity for axion searches has been launched. This Axion Detector Demonstrator (QTI_ADD) is based on the heterodyne approach to axion detection, and uses a dedicated SRF cavity design with overlapping, quasi-degenerate modes to search for axion-induced photon conversion from a driven, resonant cavity mode (pump mode) to a second, distinct mode (signal mode), with the frequency spacing between them being proportional to the prospective axion mass.

Whilst the programme is its initial stages, the conceptual design of a suitable cavity and signal acquisition system has been outlined. Of particular interest are the constraints which arise from the anticipated measurement setup, with a sub-Kelvin cryogenic detector volume now foreseen, and axion mass scans to be performed using a non-mechanical tuning system. Key design choices and implications for the expected axion search reach are discussed, and the envisioned timeline for this QTI_ ADD facility and its first measurement programme are addressed.

Thursday Poster Session - Board: THP81 / **328**

Design of a fast reactive tuner for 1.3 GHz TESLA cavities at MESA

Author: Ricardo Monroy-Villa[1]

Co-authors: Florian Hug [1]; Ilan Ben-Zvi [2]; Timo Stengler [3]

[1] *Johannes Gutenberg University Mainz*

[2] *Brookhaven National Laboratory; Stony Brook University*

[3] *Institut für Kernphysik*

Corresponding Author: rmonroyv@uni-mainz.de

This work presents a state-of-the-art design of a Ferroelectric Fast-Reactive Tuner (FE-FRT), capable of modulating high reactive power in TESLA type cavities on a microsecond time scale. The Mainz Energy-Recovering Superconducting Accelerator employs superconducting radio frequency cavities operating at 1.3 GHz, achieving quality factors on the order of 10^10. However, detuning of +/-25 Hz induced by microphonics have led to the use of strong coupling for the fundamental power coupler, requiring high-power amplifiers, orders of magnitude above the intrinsic dissipation. Current

solutions to mitigate microphonics rely on piezoelectric tuners, which are not fast enough for the spectral range of the microphonics. A novel alternative is the FE-FRT, a technology made possible by the development of low-loss ferroelectric materials, which offer sub-microsecond response times. Analytical results are provided along with their validation through finite-element simulations. The FE-FRT is expected to handle substantial reactive power while offering a tuning range of 50 Hz in these types of cavities, resulting in a reduction in peak forward RF power by about an order of magnitude.

Funding Agency:

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Thursday Poster Session - Board: THP82 / **320**

LCLS-II HE cryomodule test results after an uncontrolled vacuum event

Author: Andrew Cravatta[1]

Co-authors: Genfa Wu [1]; Dominique White [2]; Tug Arkan [2]; James Maniscalco [2]

[1] *Fermi National Accelerator Laboratory*

[2] *SLAC National Accelerator Laboratory*

Corresponding Author: genfa@fnal.gov

During the preparation for the installation of the LCLS-II HE cryomodules, one previously qualified cryomodule experienced an uncontrolled vacuum event. The cavity string vacuum unexpectedly increased to 2 × 10^ (-3) Torr. Simulation showed the vacuum incident may have introduced 0.1 µm sized particulates into the cavity RF volume. Careful analysis of the particulates' path and migration indicated that the particle migration was negligible except for finer particles smaller than 0.1 µm. A repeat test of the cryomodule verified the initial analysis. The cryomodule's performance was intact. All cavities experienced no detectable x-ray as in its previous test. Particles of the smaller size may not cause harm to the cryomodule at the admin limit of the HE cavity gradients. This article describes the vacuum event, analysis, and cryomodule test results before and after the event.

Funding Agency:

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Thursday Poster Session - Board: THP83 / **322**

Improving the performance of mid-T baked niobium cavities through post-bake surface treatment

Author: Vijay Chouhan[1]

Co-authors: Alexandr Netepenko [1]; Andrew Cravatta [1]; Genfa Wu [1]; Tim Ring [1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: genfa@fnal.gov

Medium temperature (mid-T) baking of niobium superconducting radio-frequency cavities at 300–350 ℃ in a vacuum furnace is known to enhance the quality factor (Q_0). However, despite this improvement, cavities treated with this process often prematurely quench at relatively low accelerating fields. This limitation is suspected to arise from the formation of surface contaminants, such as niobium carbides, during the furnace bake. To investigate the influence of potential surface contamination, this study applied an ultralight chemical removal to 1.3 GHz and 650 MHz single-cell cavities that had undergone medium-temperature baking. The removal of the top RF surface layer led to a notable improvement in the quench field and Q_0, indicating a beneficial effect of eliminating possible surface residues introduced during the bake.

Keynote - Board: KEY1 / **324**

Dawn of new era for nuclear physics prevailed by the 2nd generation RI beam accelerator facilities in the world

Author: Hiroyoshi Sakurai[1]

[1] *RIKEN Nishina Center*

Corresponding Author: sakurai@ribf.riken.jp

The mission of the RIKEN Radioactive Isotope Beam Factory (RIBF) is to improve our understanding of the mechanism of synthesis of elements in the universe via experiments using intense heavy-ion beams. The RIBF accelerator complex consists of booster ring cyclotrons and three injectors of AVF cyclotron, RIKEN Linear ACcelerator (RILAC), and RILAC2. Beams of ion species ranging from hydrogen to uranium are accelerated in accordance with experimental requirements. The RIBF has started providing intense heavy-ion beams for RI beam production and achieved the beam power of 10 kW for the uranium beams. Recently the projects of the second generation heavy-ion facilities are on-going all over the world, FAIR in Germany, SPIRAL2 in France, FRIB in the USA, RAON in Korea, and HIAF in China. Most of them are based on superconducting linac aiming at higher beam power. Obviously the field of nuclear physics is going into a new era. This talk will share the new coming prospects of nuclear physics explored with these 2nd generation facilities.

Friday Oral Session: A - Board: FRA01 / **92**

PIP-II SRF cavities performance and field emission mitigation strategy

Author: Jeremiah Holzbauer[1]

[1] *Fermi National Accelerator Laboratory*

Corresponding Author: jeremiah@fnal.gov

PIP-II project is based on 5 types of SRF cavities. Developing the linac includes several advances in the SRF cavity processing and cryomodule design and assembly. This talk will summarize these advances, report recent results, and plans for further developments.

Friday Oral Session: A - Board: FRA02 / **40**

SRF technology challenges for the electron ion collider

Author: Zachary Conway[1]

Co-authors: Zenghai Li [2]; Shaoheng Wang [1]; Philip Denny [1]; Sergey Kuzikov [1]; Alejandro Castilla [1]; Alex Zaltsman [3]; Binping Xiao [3]; David Savransky [1]; Freddy Severino [3]; Gary Cheng [1]; Geetha Narayan [3]; Graeme Burt [4]; Haipeng Wang [1]; Jean Clifford Brutus [3]; Jean Delayen [1]; Jesse Fite [3]; Jiquan Guo [1]; John Buttles [5]; Joseph Matalevich [1]; Katherine Wilson [1]; Kevin Mernick [3]; Kevin Smith [3]; Nabin Raut [1]; Naeem Huque [1]; Niklas Templeton [6]; Pashupati Dhakal [1]; Robert Rimmer [1]; Sarra Bira [1]; Silvia Verdu-Andres [3]; Subashini De Silva [7]; Wencan Xu [3]

[1] *Thomas Jefferson National Accelerator Facility*

[2] *SLAC National Accelerator Laboratory*

[3] *Brookhaven National Laboratory*

[4] *Lancaster University*

[5] *Bailey Tool & Manufacturing (United States)*

[6] *Science and Technology Facilities Council*

[7] *Old Dominion University*

Corresponding Author: conway@jlab.org

The Electron Ion Collider (EIC) pushes the limits of superconducting radio frequency systems to fulfil a variety of accelerator physics requirements. Thomas Jefferson National Accelerator Facility (TJNAF) and Brookhaven National Laboratory (BNL) in partnership are leading an international collaboration designing and building 46 independent superconducting cavity resonators comprised of 4 unique cavity types. The 4 systems all operate at 2.0 K and separately provide a range of capabilities such as compensating a 25 mrad collision crossing angle with > 11 MV of 197 MHz and 3 MV of 394 MHz deflecting voltage per crab cavity, coupling up to 800 kW of power per SRF cavity compensating the 10 MW of beam losses in the 2.5 A electron storage ring, storing and ramping the energy of the 1 A hadron storage ring, and providing the high voltage necessary to rapidly accelerate single 28 nC bunches to variable energies between 5 and 18 GeV for injection into the electron storage ring. This presentation will overview the challenges and proposed solutions for these systems and outline our future plans for the high-power superconducting cavities, 500 kW fundamental power couplers, and >60 kW beam line absorbers

Funding Agency:

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Friday Oral Session: A - Board: FRA03 / **56**

Production of 1.3 GHz cavities for SHINE project

Author: Hongtao Hou[1]

[1] *Shanghai Advanced Research Institute*

Corresponding Author: houht@sari.ac.cn

The production of over hundreds of 1.3 GHz high-Q superconducting cavities for the Shanghai High repetition rate XFEL and extreme light facility (SHINE) has now been successfully carried out. Both high temperature nitrogen doping (N-doping) recipe and mild temperature (Mid-T) baking recipe have been adopted to achieve high-Q performance. The main challenge for SHINE mass production is to promise high quality from niobium materials to cavities production. SHINE provided high purity niobium and NbTi materials to each supplier. The production was shared by five companies to provide cavities at different stages. In the talk, experience with the 1.3 GHz high-Q cavities for SHINE will be present and main performance including mechanical properties and Q0-Eacc curve will be reported. The lessons we learned during production will be discussed. Cavities performance from vertical test to horizontal test will be reported, too.

Friday Oral Session: A - Board: FRA04 / **41**

Cryogenics for SRF accelerator facilities - recent developments and challenges

Author: Nusair Hasan[1]

[1] *Facility for Rare Isotope Beams*

Corresponding Author: hasann@frib.msu.edu

Large-scale 4.5 K and 2.0 K helium cryogenic systems are a foundational support system for modern superconducting accelerator facilities. These are highly energy intensive systems. Large-scale efficient helium systems presently require approx. 800 W/W of cooling at 2 Kelvin (30 mbar) and 250 W/W at 4.5K. Due to the nature of the application, these systems require very high reliability (24/7/365 operation). Over the last few decades, progressive and synergistic advancements in cryogenic system operating efficiency and reliability have been made –starting from development of warm compressor skids with wide range operation, to development and implementation of the Ganni floating pressure process for efficient and high turn-down of the refrigeration systems (NASA-JSC, 12 GeV-JLab, FRIB etc.). These design and developments are successfully utilized with high turn-down capacity and substantial energy savings for large-scale helium cryogenic systems at many US Labs. The design and successful implementation of superconducting magnet quench recovery and management helped preservation of helium inventory and improved beam availability. There are still several challenges, e.g. efficient and reliable operation of small-scale 2.0 K cryogenic systems, helium recovery and purification systems that can affect reliable cryogenic system operation. In this talk, the operational experience, progress made to date, recent challenges, and the path forward are discussed.

Friday Oral Session: A - Board: FRA05 / **39**

SRF Cavity Development for the FCC-ee at 400/800 MHz

Author: Shahnam Gorgi Zadeh[1]

Co-authors: Akira Miyazaki [2]; Franck Peauger [1]; Guillaume Rosaz [1]; Hayato Araki [3]; Kellen McGee [4]; Kristof Brunner [1]; Walter Venturini Delsolaro [1]

[1] *European Organization for Nuclear Research*

[2] *Université Paris-Saclay, CNRS/IN2P3, IJCLab*

[3] *High Energy Accelerator Research Organization*

[4] *Fermi National Accelerator Laboratory*

Corresponding Author: shahnam.gorgi.zadeh@cern.ch

FCC-ee is the baseline for future lepton collider projects at CERN. To meet specific physics objectives, CERN is developing two types of accelerating cavities in collaboration with international partners. For low-energy applications, namely the Z pole, W, and H physics cases, CERN is working on 400

MHz seamless cavities with Nb-coating technology, in partnership with KEK. Prototype cavity development is ongoing at CERN using HiPIMS technology. In parallel, a novel bulky Nb-coated cavity design, known as SWELL, is undergoing testing at CERN. For higher-gradient applications required for tt-bar operation and the booster, 800 MHz bulk niobium cavities are being developed in collaboration with Fermilab, Cornell, and IJCLab. This paper will cover the SRF cavity development for FCC-ee.

Friday Oral Session: A - Board: FRA06 / **13**

Test of the first RF dipole cryomodule for HL-LHC

Author: Nuria Valverde Alonso[1]

[1] *European Organization for Nuclear Research*

Corresponding Author: nuria.valverde.alonso@cern.ch

The first RF Dipole crab cavity cryomodule under the HL-LHC project was jointly built between CERN and UK-STFC to carry out proton beams tests in the SPS machine. In 2024, the cryomodule was tested in the CERN horizontal test facility prior to its installation in the SPS. During the acceptance tests two critical non-conformities on the fundamental power couplers were detected. The mitigation of these non-conformities and the subsequent validation tests of the cryomodule tests leading to successful CW operation is presented. Some key aspects on RF, cryogenics stability, alignment and frequency tuning are addressed.

Funding Agency:

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Friday Oral Session: B - Board: FRB01 / **66**

Experimental demonstration of the slotted waveguide elliptical SWELL cavity for high intensity SRF accelerators

Author: Franck Peauger[1]

Co-authors: Guillaume rosaz [1]; Igor Syratchev [1]; Mathieu Therasse [1]; Olivier Brunner [1]; Shahnam Gorgi Zadeh [1]

[1] *European Organization for Nuclear Research*

Corresponding Author: franck.peauger@cern.ch

In the context of the FCC study where strongly damped RF structures are required to accelerate high beam currents, a new slotted waveguide cavity called SWELL has been proposed. The design is based on an elliptical cavity shape split into four quadrants making it compatible with Niobium-on-Copper coatings. A first prototype at 1.3 GHz has been fabricated at CERN to demonstrate the feasibility of this new cavity topology. This paper reports on the manufacturing steps of the individual quadrants, the surface preparation including chemical electropolishing and thin film coating, and the assembly process of the cavity in clean environment. First RF tests results of this prototype at cryogenic temperature are presented and compared with standard tesla cavity performances. The

measurement of the trapped flux surface resistance is also reported and discussed. Finally, we highlight advances in the design and development plan of such cavity concept for future high intensity SRF accelerators.

Friday Oral Session: B - Board: FRB02 / **87**

Development of a traveling-wave (TW) structure for high gradients

Author: Kellen McGee[1]

Co-authors: Alex Netepenko [1]; Crispin Contreras-Martinez [1]; Fumio Furuta [1]; Kensei Umemori [2]; Nikolay Solyak [1]; Pavel Avrakhov [3]; Roman Kostin [3]; Sergey Kazakov [1]; Timergali Khabiboulline [1]; Vyacheslav Yakovlev [1]

[1] *Fermi National Accelerator Laboratory*

[2] *High Energy Accelerator Research Organization*

[3] *Euclid Techlabs (United States)*

Corresponding Author: kem11235@fnal.gov

High-gradient superconducting RF structures are of keen interest to next-generation linear colliders because they offer substantial savings in terms of reduced construction cost by shortening the machine, and reduced operating costs. The gradient of bulk niobium superconducting RF structures is fundamentally limited by the maximum surface magnetic field these structures can sustain before quenching. While a history of sophisticated and complex niobium surface processing techniques has aimed to increase the niobium critical surface field, it is also possible to increase the accelerating gradient by altering the cavity geometry and accelerating mode in order to improve the ratio of the accelerating gradient to peak surface magnetic field. Traveling wave structures do just this by using geometric means to operate in the traveling-wave mode to increase the structure's transit time factor. With increased transit-time factor, higher gradients such as ~70 MV/m can be achieved under the same peak surface fields that otherwise limit 1.3 GHz cavities to below ~50 MV/m. These structures use proven Nb fabrication and processing techniques. Prototype development activities for a 3-cell structure, and a proof-of-principle waveguide loop are under development at FNAL. This talk shall provide an update of activities at FNAL, and worldwide collaboration on traveling wave structure development.

Friday Oral Session: B - Board: FRB03 / **35**

Overview on current activities of conduction-cooled SRF accelerators and their applications

Author: John Vennekate[1]

[1] *Thomas Jefferson National Accelerator Facility*

Corresponding Author: vennekate@jlab.org

When Nb_3Sn was reintroduced to the SRF community as an alternative to pure niobium, one key motivation has been to reduce the cryogenic requirements of new and existing accelerators by shifting from 2 K to 4 K operation. Meanwhile, a variety of implementations beyond research machines are being explored. The combination of Nb_3Sn with conventional cryocoolers, enabling cryogen-free operation, has paved the way for the development of compact, standalone systems suitable for applications far beyond research, such as enhancing the durability of synthetics via crosslinking or sterilizing food and medical equipment, as well as environmental cleanup when it comes to

decontaminating liquid and solid waste material. So, while fundamental R&D continues to refine Nb_3Sn resonators, exploring improvements such as replacing the niobium substrate with copper, parallel research efforts are investigating how the increased beam power provided by SRF could expand the commercial use of electron beams. This presentation aims to deliver a comprehensive overview of ongoing research efforts to harness the benefits of SRF through Nb3Sn and conduction cooling.

Friday Oral Session: B - Board: FRB04 / **28**

Perspectives of superconducting materials in SRF at high fields for large physics experiments

Author: Nicola Pompeo[1]

Co-authors: Alessandro Magalotti [2]; Andrea Alimenti [2]; Enrico Silva [2]; Kostiantyn Torokhtii [3]; Pablo Vidal García [2]

[1] *Università degli Studi Roma Tre*

[2] *Roma Tre University; Istituto Nazionale di Fisica Nucleare, Sezione di Roma Tre*

[3] *Roma Tre University*

Corresponding Author: nicola.pompeo@uniroma3.it

Large experiments in fundamental physics such as the detection of dark matter axions [1] or new particle accelerators like the CERN FCC [2], can greatly benefit from the low surface impedance Zs of superconductors (SC) in high magnetic fields H. In the pursuit of high-Q SC cavities (haloscopes), the understanding and control of high frequency vortex motion, the main dissipative channel acting in the mixed state, is of paramount importance. We propose a microwave (ν=8-27 GHz) study at high H, ≤12 T, of Zs in Nb3Sn samples grown by different techniques: high isostatic pressure sintering (HIP), vapor diffusion (VD), and DC magnetron sputtering (DCMS). Using a dual frequency dielectric loaded resonator, vortex dynamics parameters are extracted. Several results are deduced for the various Nb3Sn samples: the HIP sample presents effective, albeit collective, pinning; the VD sample exhibits a weak collective pinning overcome already at a few T; the DCMS sample shows a marked signature of Josephson coupled network of grain boundaries, sites for the effective pinning observed. Secondly, we present a broad comparison of the potential performances of several SC, evaluated in a large (T, H, ν) parameter space [3]. It is inferred that, althoughvortex pinning plays obviously a major role, the often-disregarded flexibility of vortex lines and the penetration depth strongly affect haloscopes Q, so that the choice of the material is not obvious.

Footnotes:

[1] D Alesini et al, Phys. Rev. D 99, 101101(R) (2019)
[2] S Calatroni, IEEE Trans. Appl. Supercond. 26, 3500204 (2016)
[3] A Alimenti et al, Instruments 6, 1 (2022)

Funding Agency:

partially supported by:
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MUR-PRIN Project IronMOON Grant No. 2022BPJL2L,
FCC collaboration under MoU Addendum FCC-GOV-CC-0218 (KE5084/ATS).

Friday Oral Session: B - Board: FRB05 / **11**

Detection of high-f gravitational waves using SRF cavities

Authors: Marc Wenskat[1]; Bianca Giaccone[2]

[1] *Universität Hamburg*

[2] *Fermi National Accelerator Laboratory*

Corresponding Authors: marc.wenskat@desy.de, giaccone@fnal.gov

Today, apart from some isolated R&D efforts, there are no GW experiments, yet which explore a large part of the vast frequency range above the LIGO/Virgo band. It is planned to establish an experiment at DESY and FNAL to search for high-frequency GWs in the frequency range of 10 kHz to 100 MHz. The basic idea is to use superconducting radiofrequency (SRF) cavities to detect tiny harmonic deformations induced by GWs which change the boundary conditions of the oscillating electromagnetic field.

This talk deals with a brief motivation of this search, which dictates the challenging environmental boundary requirements, and the R&D to operate a cavity using a LLRF system which pushes beyond state-of-the-art accuracy and resolutions and a seismic noise mitigated cryostat at 1.8 K.

A focus of the presentation will be the warm and cold commissioning of a prototype cavity, built 20 years ago during the MAGO collaboration, and its first measurement in our collaborative research project. We will address the questions “What can we learn from this prototype?”and “how to design and build an optimized cavity for high-f GW search?”and the preparations for a first physics run in 2026 to explore an uncharted phase space in GW physics.”

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Anhui Huadong Photoelectric Technology Research Institute Co., Ltd.

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安徽华东光电技术研究所有限公司位于安徽省芜湖市高新技术开发区华夏科技园内，占地334,000平方米。目前公司主要业务包括微波真空器件产品的研发、生产和销售。

公司主要产品包括高功率耦合器、定向耦合器、高次模吸收器、BPM和馈通等各种无源器件，以及电子枪、波导窗、钛离子泵等。

Anhui Huadong Photoelectric Technology Research Institute Co., Ltd. is located in Huaxia Science and Technology Park, High-tech Development Zone, Wuhu City, Anhui Province, covering an area of 334000 square meters. The company is currently dedicated to the R&D, production, and sales of microwave vacuum device products.

Its core products include high-power couplers, directional couplers, high-order mode absorbers, BPM (Beam Position Monitors), feedthroughs, and other passive devices; include Electron guns, waveguide windows, titanium ion pumps and other key devices.

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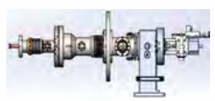
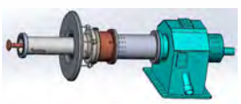
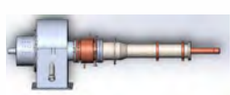
162.5MHz双窗耦合器
162.5MHz dual window coupler



1.3GHz双窗耦合器
1.3GHz dual window coupler

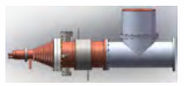


650MHz高功率输入耦合器
650MHz high-power input coupler



500MHz高功率输入耦合器
500MHz high-power input coupler

超重RFQ耦合器
RFQ coupler



BNCT02-RFQ耦合器
BNCT02-RFQ coupler

定向耦合器
Directional coupler

高阶模耦合器
High-order mode coupler

S波段功分器
S-band power divider

1.3GHz高次模吸收器
1.3GHz high-order mode absorber

1.5GHz高次模吸收器
1.5GHz high-order mode absorber

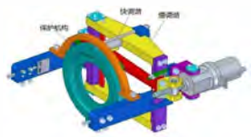
500MHz高次模吸收器
500MHz high-order mode absorber

650MHz高次模吸收器
650MHz high-order mode absorber

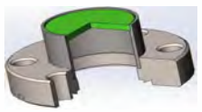
低温BPM
Low temperature BPM

200ns-BPM

300ns-BPM



调谐器
Tuner



宝石观察窗
Gemstone observation window

各种型号N型馈通
Various models of N-type feedthrough

各种SMA型馈通
Various SMA type feedthrough

各种陶瓷金属封接件产品
Various ceramic metal sealing products

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Aluminum magnesium alloy ring

Aoi Kogyo Co. Ltd.

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TEL: +81-29-857-4848, URL http://www.aoi-k.co.jp

- *Support for Innovations and Technology R&Ds by SRF Physicist and Copy/Printing Service –*

Areas:

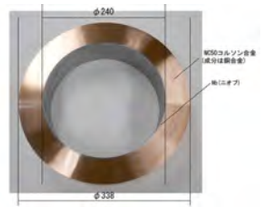
1) Materials：Niobium, Copper-Nickle Alloys（NC）
2) SRF Cavity Fabrication
3) SRF Fundamental Power Coupler
4) Cavity Tunner
5) Cavity Preparation, BCP, EP, Tumbling, and Other New Methods
6) Magnetic Shielding
7) Cryomodule
8) SRF Quantum Computer
9) High Power Sources
10) Print out Posters.

Aoi Kogyo has a patent to apply NC-alloys to Cryogenic engineer field.

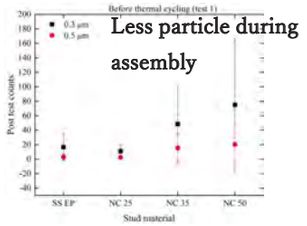
Patent for NC material applications
JAPAN PATENT OFFICE
Patent No.7126656: NC material application for low temperature technology

† Products made by NC Alloys: e.g. NC Bolts/Nuts, Nb/NC Clad Pipes

NC Bolts/Nuts

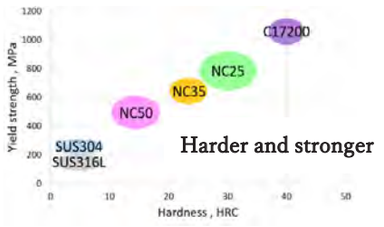


Nb/NC Clad Pipes

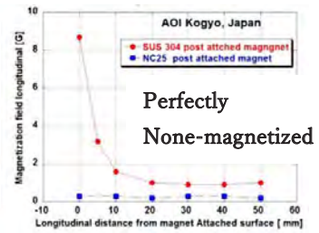


Less particle during assembly

Properties of NC: Harder, Stronger, Non-cold Brittleness issue, Perfectly Non-Magnetized, Less particle (bolts/nuts).



Harder and stronger



Perfectly None-magnetized

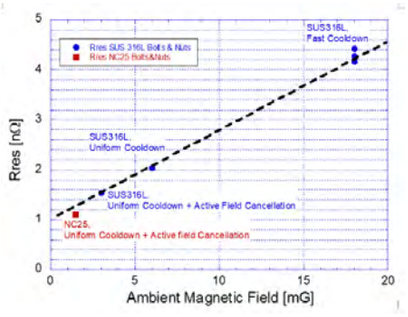
No cold brittleness issue

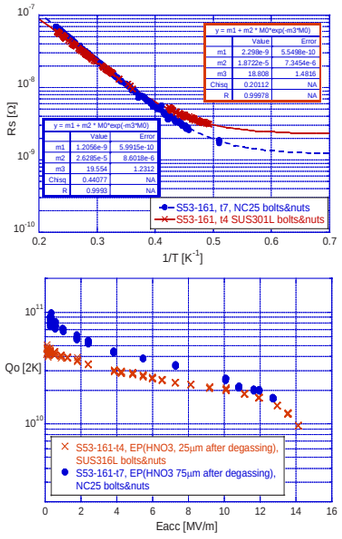
Sarpy values of NC100 at 4.3K, comparing with niobium, titanium, and niobium-titanium.

	NC50	Nb	Ti	NbTi
Sarpy value [J] at 4.3K	102	15	25 - 32	30

† Benefit for SRF Cavity Performance: High Q Performance

Reduced ambient field by the material perfectly non-magnetized and Push up Qo (FRIB results: 0.53HWRS, all SUS361L bolts nuts were replaced by NC25 ones).





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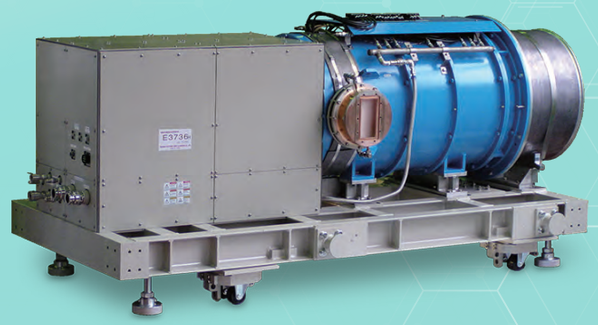

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▼ High speed measurement from 1 ms
▼ 4 ion source options provides the best solution.
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Helium leak detectors - ASM310 -

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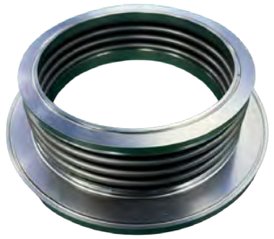

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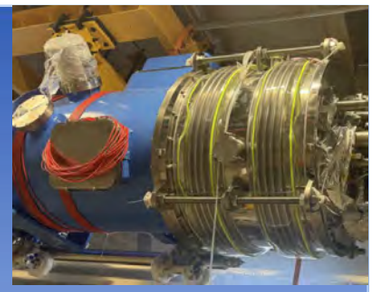
- SHINE
- CSNS、CSNS-II
- HIAF
- CiADS
- BEST



FLEXTAI

2021 年以降、JEMA は粒子加速器用途を専門とする高い技術を持つ 2 つの企業を吸収しました。

1970 年代からブルカー・バイオスピンが開発・製造してきた電源とソリッドステートアンプは、その性能と長寿命で世界的に有名であり、シグマフィの磁気回路と制御エレクトロニクスのグローバル展開に 7 年間貢献した後、2021 年に JEMA グループに加わりました。

サイクロトロン用モジュラー電源の開発・製造に約 40 年間特化してきた Jema SA を含む 2 つの事業体の合併により、JEMA は、科学、医療、産業市場向けに製品を提供できるようになり、世界的に製品ラインナップを大幅に強化することができました。

JEMA が提供する**電源**装置には以下のものがあります：

- **カスタマイズ製品：**さまざまなトポロジー、サイリスタまたは一次または二次スイッチング（START レンジ）、4-Quadrant または unipolar の低電力（コレクター）または高電力（最大 3MW、30kA）。
- **モジュール製品**：CIME、PRISME、MOSAIC シリーズは、それぞれ 5kW の独立した 4 つの出力を持つ 19 インチ 20kW モジュールをベースにしています。

LDMOS または GaN トランジスタを搭載した**ソリッドステート RF アンプは**、以下の周波数・出力領域をカバーしています：

- 30MHz から 3GHz まで
- 定格出力 500kW まで。

さらに、JEMA は製品の性能を向上させ、最新技術を取り入れるために、研究開発に継続的に投資しています。

Since 2021, JEMA has been the result of the merger of two high-performance companies specializing in particle accelerator applications.

The power supplies and solid-state amplifiers developed and produced by Bruker Biospin since the 1970s, world-renowned for their performance and longevity, joined the JEMA Group in 2021, after contributing for seven years to the development of Sigmaphi's global offering of magnetic circuits and control electronics.

The merger of the two entities, including Jema SA, which has also specialized for some forty years in the development and production of modular power supplies for cyclotrons, has enabled JEMA to develop a considerably enhanced global offering, which is now able to offer its products to the scientific, medical and industrial markets.

The range **of power supplies** offered by JEMA includes :

- **Customized products**; in different topologies; with thyristor or primary or secondary switching (START range); 4Quadrant or unipolar, low power (Correctors) or high power (up to 3MW, 30kA).
- **Modular products**; CIME, PRISME and MOSAIC range based on 19" 20kW modules with 4 independent outputs of 5kW each.

The range of **Solid State RF Amplifiers** equipped with LDMOS or GaN transistors, covers the following frequency ranges:

- From 30MHz to 3GHz
- With power ratings up to 500kW.

In addition, JEMA continually invests in R&D to improve the performance of its products and incorporate the latest technologies.

KAT **(Kiswire Advanced Technology Co., Ltd.)**

KAT is a global leading superconducting wire company expanding its business into superconducting accelerator devices.

We develop high-performance superconducting wires and have been in collaboration with CERN to develop High Jc Nb_3Sn wire for the FCC project since 2017.

In 2018, as the first step in entering the superconducting accelerator devices business, KAT delivered a prototype HWR cryomodule to the Institute for Rare Isotope Science (IRIS) in Daejeon, Korea.

Since 2021, KAT has been developing superconducting cavities.
In 2023, we successfully developed a 1.5 GHz 3rd Harmonic Cavity for Synchrotron light source in collaboration with Korea University. In 2025, we fabricated the 1.3 GHz single-cell R&D Cavity under the research collaboration for ILC SRF cavity between KEK and Korea University. All of these cavities have fully met the required specifications.

KAT is currently manufacturing a prototype SSR2 cryomodule awarded in December 2024 for the RAON project in Korea and developing the fabrication of 1.3 GHz 9-cell cavities for ILC under the research collaboration between KEK and Korea University.

About KAT

KAT has been developing the superconducting technologies over 20 years.

Superconducting Devices

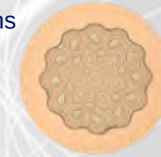
SSR2 cryomodule prototype for RAON (**Collaboration with IHEP**)

2024 ~

Cavity fabrication technology verified by SARI and KEK

2021 ~ 2025

2025 ~
Award **DTT CS** strand
18.4 tons
Nb_3Sn



2023 ~
Start **SUCCEX** project in Korea.
1.4 tons **High Jc**
5.9 tons **Nb_3Sn**

Supply **Cryomodule** for RAON & **Cryostats** to MHI-MS

2018 ~ 2019

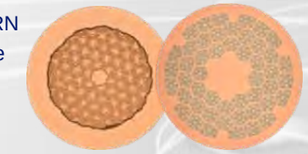
Supply 1.5T MRI magnet to TCL, China (KAT NbTi wire applied)

2019 ~ 2022
Supply **Nb_3Sn** of 55 tons for DTT TF coil

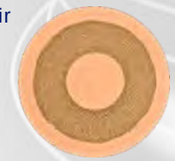
2015

Foundation of KAT

2017 ~ Now
R&D contract with CERN for **High Jc Nb_3Sn** wire



2014 ~ 2021
Start R&D project of **NbTi** and **MgB_2** wires funded by Korean Government



2004

2009
Supply **Nb_3Sn** of 137 tons for ITER (TF, CS Coils, 2009-2016)

2006
Supply **Nb_3Sn** of 2 tons for KSTAR (PF Coil)

1998
Start R&D of Nb_3Sn superconducting wire (Kiswire R&D Center)

Superconducting Wires

KYOCERA

ULTRA HIGH VACUUM COMPONENTS

ULTRA HIGH VACUUM COMPONENTS

超高真空用部品

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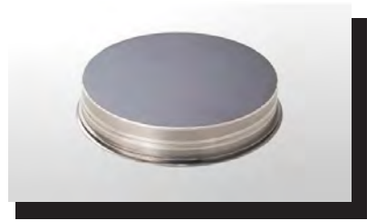
KYOCERA Corporation

RF Window Ceramics

MHz and GHz high frequency RF windows utilize low dielectric loss ceramics, In addition to conventional ceramic materials, Kyocera offers additional lines of low loss materials (AO479B, AO479U, SN287A) to support demands in wide range of frequency applications.

Doughnut shape

Cylinders



Metal Brazing

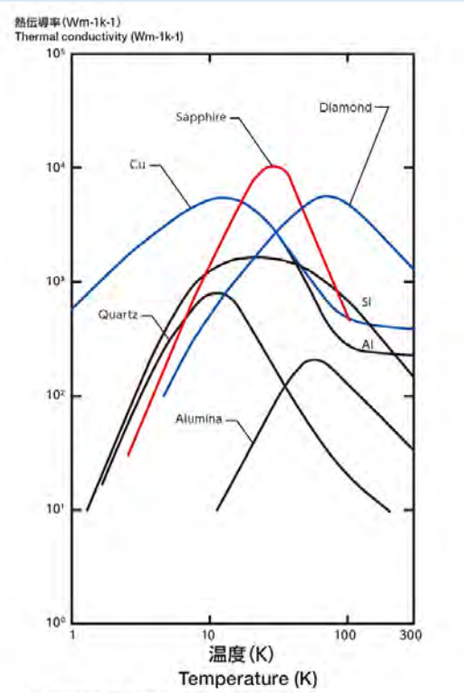
Sapphire Hermetic Components

Kyocera can manufacture state of the art sapphire insulator to hermetic components.

- Sapphire is an insulating material with high thermal conductivity that is suitable in low temperature ranges.
- High purity niobium (RRR>300) and other metal options available for brazing assembly.

Sapphire Feedthrough

Low Temperature
Thermal Conductivity



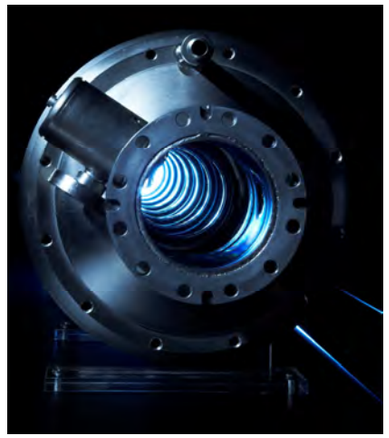
Reference：E.Tward・R.Klrschman、「Proceedings of the Cold Electronics Workshop」、1984、p12

MITSUBISHI HEAVY INDUSTRIES

Mitsubishi Heavy Industries Machinery Systems, Ltd.

Our original accelerator was normal conducting S-band accelerating structures delivered to Tokyo University in 1959. We manufactured the accelerator components at the production facilities of Nagoya Aircraft Manufacturing Company. In the years since we have participated in most of Japan's large-accelerator projects as a specialist in precision machining technology for non-ferrous metals such as copper and aluminum, a specialty we acquired through the manufacture of aircraft parts. We have also improved our accelerator technology by developing components that satisfy the specifications and performance standards required by researchers and research institutes.

We have been developing the top-level accelerator components in the world to support the passion and achievements of researchers who are pursuing research and exploring day and night in various institutes at home and abroad in the interest of human beings and society.



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Examples and Achievements

MITSUBISHI HEAVY INDUSTRIES

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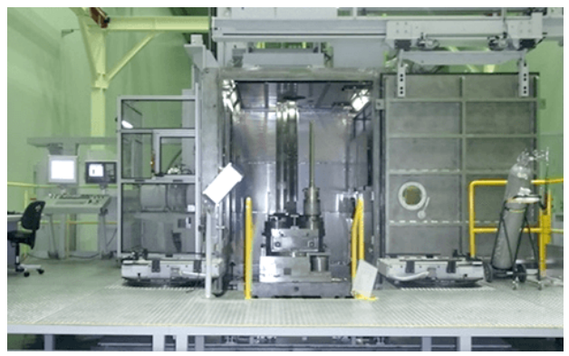

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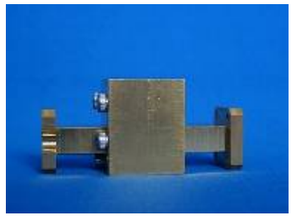
Development System

MOVE THE WORLD FORWARD MITSUBISHI HEAVY INDUSTRIES GROUP

Polarized Wave Separator



Polarized Wave Separator is classified into two types: Circular Polarization Wave Separator and Linear Polarization Wave Separator.

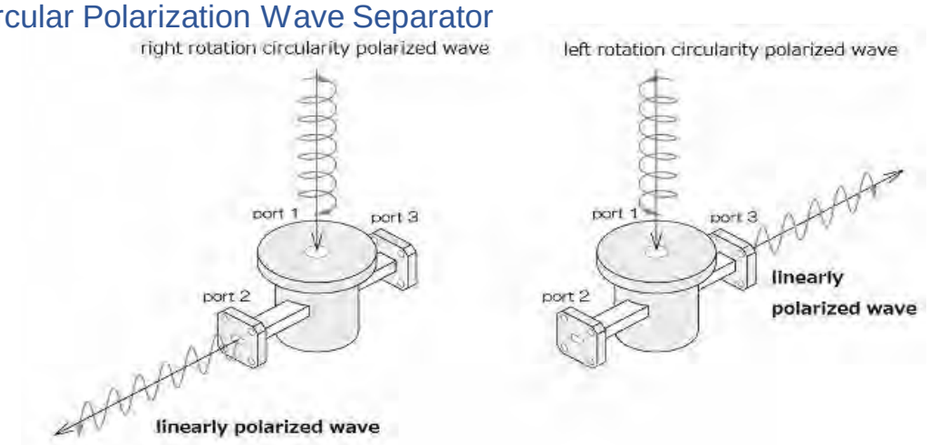
Circular Polarization Wave Separators separate the circularly polarized wave input to the circular waveguide into vertically linearly polarized waves and horizontally linearly polarized waves.

Linear Polarization Wave Separators separate orthogonal linearly polarized waves input to the waveguide into vertical linearly polarized waves and horizontally linearly polarized waves.

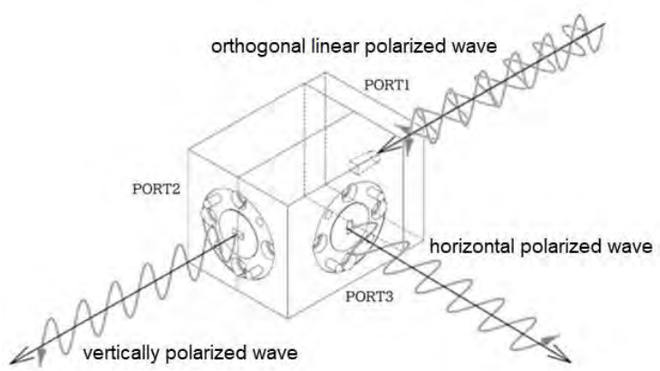
This product also supports analysis of flattening factor of elliptically polarized waves, which is particularly important in astronomical observations.

As the unit is composed entirely of metallic components, it can be used in ultra-low temperature environments (down to ~1 K).

◆ Circular Polarization Wave Separator



◆Linear Polarization Wave Separator



Polarization Switch of Linearly polarized wave and Circularly polarized wave

This product is an instrument that enables Measurement in four patterns (A,B,C and D) without replacing the waveguide device. In the past, measurement was performed by replacing straight waveguides, twisted waveguides, and the like. This product can switch the external signal electrically by internal control without replacing the waveguide device.

A,B,C and D stand for vertical polarization, horizontal polarization, right circular polarization, and left circular polarization, respectively.

◆Example of Measurement Data

Frequency range	WR5 140GHz ～170GHz
Switching speed	1 second
Power Consumption	15W
Supply voltage	DC24V
Operating temperature range	5℃ ～ 40℃
Operating method	Manual operating Automatic operating(RS232C)

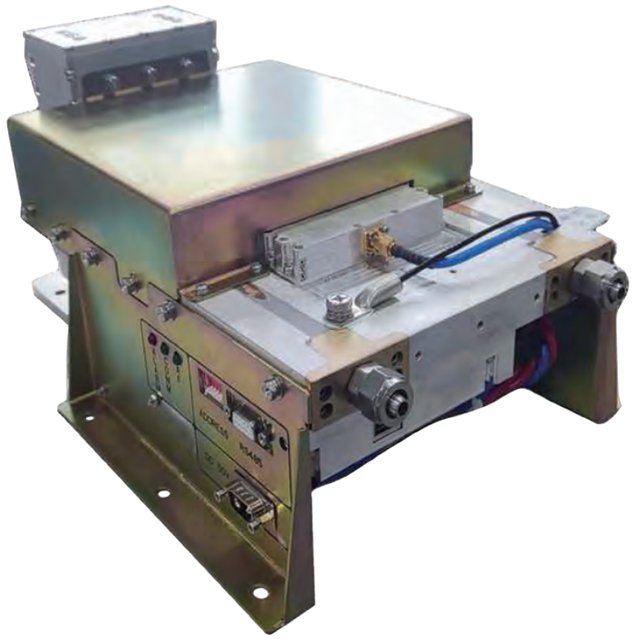
We manufacture according to your requests for frequency range, material etc.

OSHIMA Prototype Engineering Co., Ltd.

3-10-28 Nishikubo Musashino-shi Tokyo 1800013 JAPAN

TEL +81.422.52.0167 www.oshimashisaku.jp

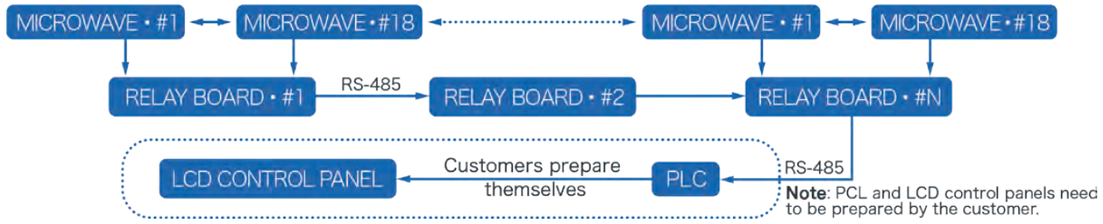
G1 1000W Solid State Power Source



Project	Feature
Work center frequency	2450MHz
Signal type	CW
Working bandwidth	2425~2475MHz
Rated output power	+10M bandwidth 1000W +25M bandwidth 900W
Output power adjustment range	+10M bandwidth 10W~1000W continuously adjustable +25M bandwidth continuously adjustable from 10W to 900W
Whole machine DC efficiency	0.55
Frequency stability	±50ppm
Second harmonic suppression	⩽-30dBc
Stray	⩽-55dBc
Power stability	⩽±15W @1000W
RF leakage	⩽2mW/cm2@30cm
Agreement	RS485
Cooling Method	Water cooling

MGT Magnetron Microwave Power Generator

Connection Diagram



Electrical Parameters	
Input voltage	190Vac to 264Vac
Maximum input current	10Amax. at full load condition
Leakage current	Less Than 1.7mA,@220Vac input
AC input	220V 10A max
Communication link	modbus

Differences Between Series			
Proiect	MGT ECO	MGT PRO	MGT PLUS
Microwave power	850W fixed	300~1000W	300~1000W
Microwave frequency	2450±50MHz	2450±50MHz	2450±50MHz
Whole machine warranty	12months	12months	15months
Magnetron warranty	6months	12months	15months
Control method	None	Modbus	Modus/PWM FM

research instruments

RI Research Instruments GmbH – SRF2025

We are a global leader in the design, development and manufacturing of advanced particle accelerators. With a commitment to excellence and innovation, we provide state-of-the-art solutions for scientific research, medical applications, and industrial processes. Our expertise spans from the production of custom accelerators and high-precision components to comprehensive engineering services, making us a trusted partner for worldwide academia and industry.

SRF Cavities and Module Manufacturing

We understand the requirements for advanced SRF solutions, and our capabilities cover the entire production process, from design and prototyping to series production and testing.

Extensive experience: We have manufactured over 2200 SRF cavities so far and are the world leading supplier for all types of SRF cavities

Precision manufacturing: We utilize advanced manufacturing techniques including high-precision forming and deep drawing, electron beam welding, vacuum brazing, TIG-welding, CNC turning and milling, CMM-measurements, NDT, RF-measurements and tuning

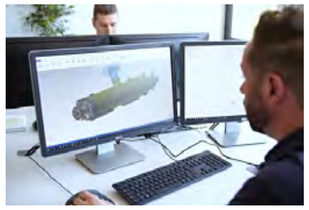
Advanced surface treatment: Nitrogen doping, electropolishing, buffered chemical polishing, high-pressure rinsing in ISO4-certified cleanrooms

Module assembly: Integration of cavities, couplers, tuners, and cryogenic components into complete SRF modules in our cleanrooms

Service & Integration: We offer maintenance services and the integration of SRF modules into larger accelerator systems

From concept to delivery

We transform complex ideas to solutions. With a dedicated team of over 430 professionals, including approx. 160 physicist, engineers, and technicians, we possess the in-house expertise and comprehensive capabilities to guide your project from its initial concept all the way through successful delivery and integration.



We offer

Superconducting and normal-conducting accelerator systems & modules: Tailored solutions for research and industrial applications, designed to meet precise project requirements.

High-precision accelerator components: Manufacturing of key components such as RF cavities, cryomodules, RF couplers, Pulsed Power Systems and beamlines, ensuring seamless integration and peak performance.

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Expertise: Decades of experience in the field, backed by a team of highly skilled engineers and physicists.

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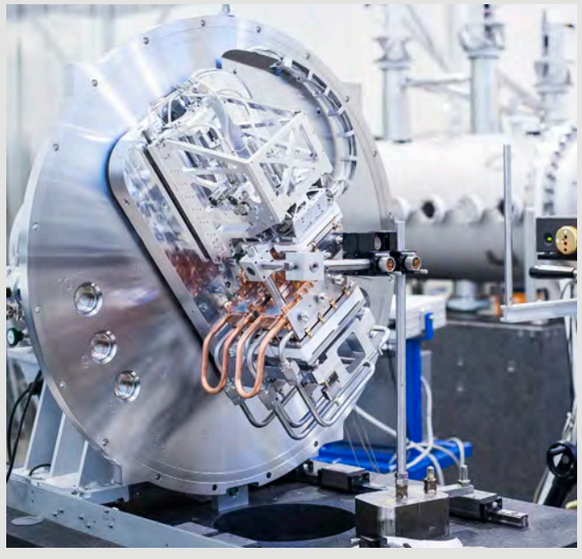
Integrated Solutions for Particle Accelerators


Courtesy of PSI



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LARGE CAPACITY GM-JT CRYOCOOLER

NEW

RJT-100ST 9.0W @ 4.2K(Stage Type)
RJT-100RC 8.5W @ 4.2K(Recondensation Type)

- LARGE COOLING CAPACITY
- LOW POWER CONSUMPTION (SUPERIOR EFFICIENCY)
- SUPERIOR TEMPERATURE-STABILIZING PERFORMANCE

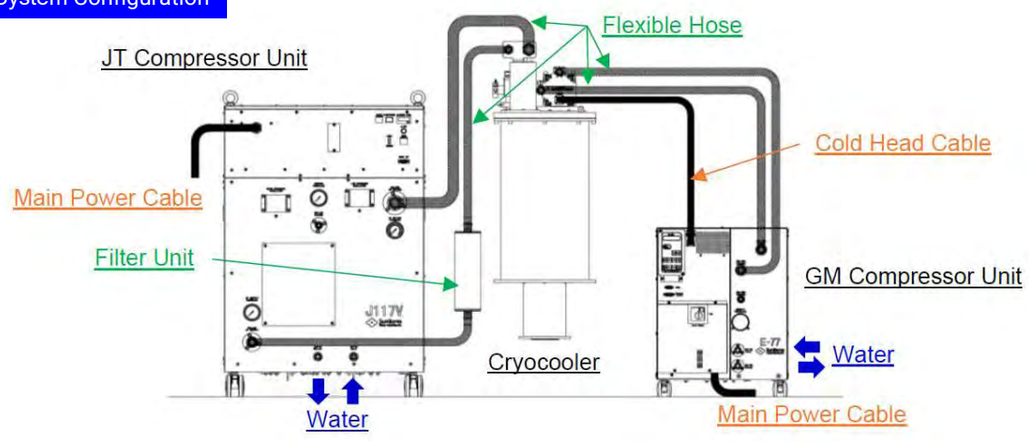
※E-77A(Comp. for GM) is required.

GM-JT Cryocooler

RJT-100ST RJT-100RC

JT Compressor

System Configuration

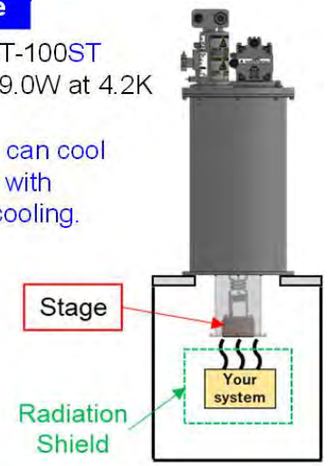


Sumitomo Heavy Industries, Ltd.

Stage type

- Model: RJT-100ST
- Capacity: 9.0W at 4.2K

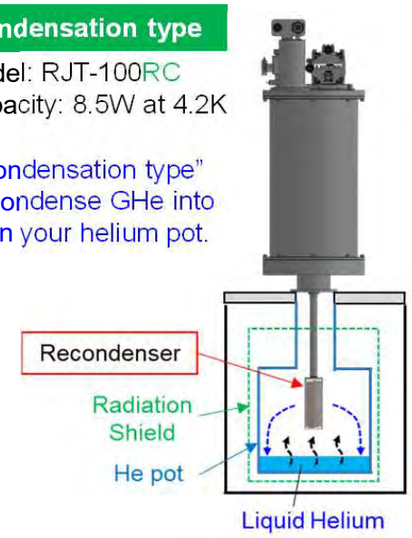
"Stage type" can cool your system with conduction cooling.



Recondensation type

- Model: RJT-100RC
- Capacity: 8.5W at 4.2K

"Recondensation type" can condense GHe into LHe in your helium pot.



Item	Specification	
GM-JT Cryocooler Model No.	RJT-100ST (Stage type)	RJT-100RC (Recondensation Type)
Cooling Capacity	9.0W@4.2K	8.5W@4.2K
Power Consumption	J117V : 6.6kW or less E-77A : 7.5kW or less	
Compressors Input power LV or HV	LV : AC200V class at 50/60Hz, 3 phase HV : AC400V class at 50/60Hz, 3 phase	
Compressors Cooling System	Water cooling (Both J117V and E-77A)	
Environmental Conditions	Indoors (without dew) Ambient temperature: 5 ~ 28deg.C, Humidity: 25~85%RH	
Outside Dimensions, Weight	Φ350mm H:1040mm (60kg)	Φ350mm H:1435mm (70kg)
	J117V : W:690mm D:800mm H:1070mm (340kg) E-77A : W:450mm D:485mm H:601mm (120kg)	
Regulatory Compliance	UL / cUL CE, RoHS UKCA	
Maintenance Interval	10,000h (※This interval is the shortest object)	

Lean more about our products at
www.shicryogenics.com/product/rjt-100-4k-gm-jt-cryocooler-series/

Specifications are subject to change without notice.

Sumitomo Heavy Industries, Ltd.

New publication, effective December 2024.

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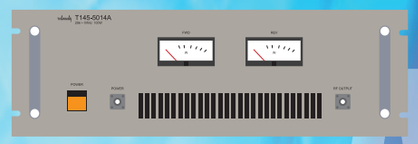
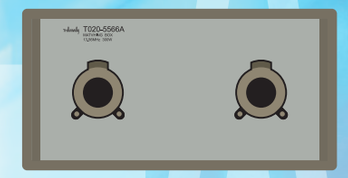
System Design

RF Power Generator



RF Amplifier



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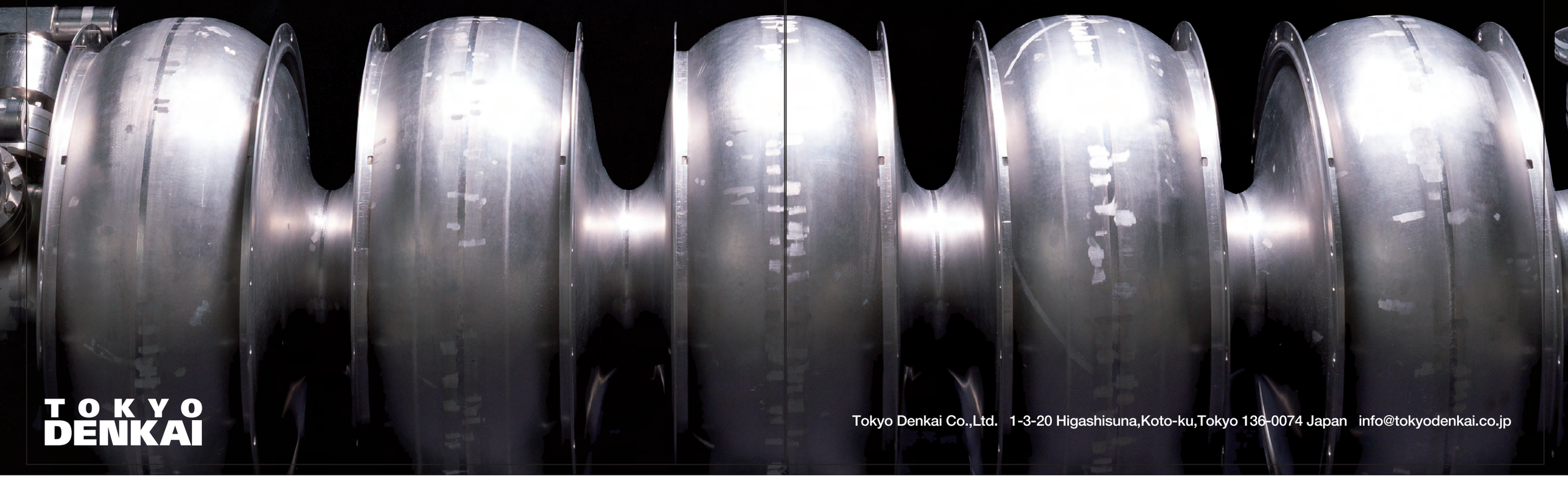

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MULTI-CHANNEL CRYOGENIC PIPELINE FOR SUPERCONDUCTING ACCELERATOR

Specifications

Channel Number: 2-7

Heat Leakage: ≤0.1W@4.2K

Pressure: 0-2MPa

Manufacture Code: EN13480

Available Materials:316(L),304(L)

Outer Vacuum Pipe Diameter: 50mm-1000mm

CRYOSTAT FOR SUPERCONDUCTING ACCELERATOR

Specifications

Operating temperature of the He vessel: 1.8k～4.2K

Operating temperature of thermal shield: 50K

Heat leakage: 7.8W@2K

Vacuum leakage rate: $\leq 1 \times 10^{-9}$pa.m³/s

Insulationhigh: vacuum+ multi-layer insulation

Design, Manufacturing &inspection: CE/PED, ASME, GB, JIS

Available Materials: 316(L),304(L), Copper (T2) Ti (TC4), G10

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340ℓ/s ～ 2400ℓ/s

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バリエーション豊富なポンプ構成
見やすい7インチタッチディスプレイ搭載

【卓上型】
ターボポンプ：HiPace 80 Neo
-NW40型 ：35ℓ/s
-ICF114型：67ℓ/s
【組み合わせ可能なポンプ】
【ﾀｰﾎﾞﾎﾟﾝﾌﾟ】HiPace80 Neo HiPace300/300H
【ﾀﾞｲｱﾌﾗﾑﾎﾟﾝﾌﾟ】MVP015-2 DC MVP030-3 DC

【可搬型】
ターボポンプ：HiPace 300 シリーズ
-ICF152型、ISO100型：260ℓ/s
【組み合わせ可能なポンプ】
【ﾀｰﾎﾞﾎﾟﾝﾌﾟ】HiPace80 Neo～HiPace800/800H
【ﾊﾟｯｸﾎﾟﾝﾌﾟ】ﾛｰﾀﾘｰﾎﾟﾝﾌﾟ：DUO 6M/11M/20M
ｽｸﾛｰﾙﾎﾟﾝﾌﾟ：HiScroll 6/12/18、他多彩な選択肢

【オイルフリーポンプ】【 スクロールポンプ 】

【 ｲﾝﾊﾞｰﾀｰﾓｰﾀ駆動/ 3機種 】 100L/min ～ 350L/min

EDWARDS nXDS シリーズ 売れ筋！
PFEIFFER HiScroll シリーズ
NEW RELEASE 50L/min 小型軽量 mXDS-3
Leybold ScrollVac シリーズ

【ﾜｰﾙﾄﾞﾓｰﾀ仕様】 50L/min ～ 250L/min
Agilent Technologies IDP シリーズ
チップシール交換：２年半周期 → キット購入にてお手元で交換可能
各種インジケーター搭載 → 適切なポンプ管理
駆動域とポンプ室はベローで隔離 → 完全オイルフリー化
静音・省エネ設計

【ロータリーポンプ】

EDWARDS
静音設計，安定性能
充実オプション
RVシリーズ 売れ筋！ 50L/min～200L/min
E2M～シリーズ 13L/min, 26L/min 340～4,200L/min
ロングセラー！

【ターボポンプ/排気ユニット】

AILIN VACUUM Invention
小型ターボ排気システム
Neo TURBO Mini
AV-EX80NEO
可搬式スリムタイプ
ターボポンプ/HiPace80：ICF114～67L/s(N2)
バックポンプ/NeoDry15G：250L/min
外径寸法/ mm：210(W)×520(D)×730(H)
ｵｲﾙﾌﾘｰﾎﾟﾝﾌﾟの定番、樫山工業社NeoDry-Gｼﾘｰｽﾞより、15G型を基調とした真空排気ｼｽﾃﾑを考案！
拡販対応中！

【オイルフリーポンプ】【 非接触型ルーツポンプ 】

Kashiyama Vacuum Solutions NeoDry E シリーズ
TOP SELLER!!
【三相200V対応モデル】
ロングライフ 低振動/低騒音 パーティクルフリー ガス循環/回収用途にも適応 様々なオプションでニーズに対応
110L/min ～ 5,000L/min

NEW RELEASE NeoDry-G シリーズ 売れてます！
E型オプションを標準装備化し付加価値を高め、スタイリッシュデザインに一新された次世代モデル
600ℓ/min, 500ℓ/min, 250ℓ/min, 100ℓ/min

Leybold EcoDry シリーズ
メンテ/5年周期 長寿命、安定性能
415L/min 580L/min 1,080L/min

PFEIFFER ACP シリーズ 短納期！
233L/min、450L/min、616L/min

EDWARDS nXR シリーズ
超小型サイズ 同クラス最軽量！ メンテ/5年周期 新製品！

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ﾐﾆUHVｹﾞｰﾄﾊﾞﾙﾌﾞ
ｵｰﾙﾒﾀﾙﾊﾞﾙﾌﾞ各種
ﾀﾞｲｱﾌﾗﾑﾊﾞﾙﾌﾞ
高真空ｹﾞｰﾄﾊﾞﾙﾌﾞ各種
ｱﾝｸﾞﾙﾊﾞﾙﾌﾞ各種
ｵｰﾙﾒﾀﾙﾊﾞﾘｱﾌﾞﾙ ﾘｰｸﾊﾞﾙﾌﾞ

【超高真空系 キャプチャーポンプ】

Agilent Technologies ★ イオンポンプ Vaclon Plus シリーズ
0.4ℓ/s ～ 960ℓ/s
ロングセラー
希ガス排気エレメントに定評 →スターセル仕様
チタンサブリメーションポンプやゲッターポンプを配備したコンビネーション型にて、排気効率をより増強することも可能
簡易コントローラは見易いタッチパネル方式に一新

EDWARDS GAMMA VACUUM ★ イオンポンプ TiTanシリーズ
0.2ℓ/s ～ 1,200ℓ/s
売れ筋！
バリエーションに富んだ本体形状にて設置スペースを有効活用
軟性の高い接続ケーブルを採用 →取り回し易く、振動伝播を軽減
チタンサブリメーションポンプやゲッターポンプを配備したコンビネーション型にて、排気効率をより増強することも可能

saes getters ★ 非蒸発型ゲッターポンプ
Capacitorシリーズ NEXTorrシリーズ HVシリーズ
50ℓ/s ～ 3,000ℓ/s
超高真空排気/最終段のマストアイテム！
新合金/ZAOの採用により、水素排気速度の向上、且つパーティクル発生が大幅に減少
希ガス排気を補うイオンポンプ搭載型/NEXTorrや高圧起動/HVタイプの拡充
各種コントローラの拡充により御利用用途に即した選定が可能
耐放射線/ベーカブル(250℃)ケーブルを標準採用

【各種真空計】★ ディスプレイ付き真空計

mks 超コンパクト設計！ 簡易計測に最適！ 限定在庫アリ！
901P型 MEMSマイクロピラニ＋MEMSダイアフラム(差圧ピエゾ)
・従来の熱伝導率ゲージよりも大幅に高い精度、安定性、再現性、および高速応答時間を実現
・ガス依存しない正確な測定
・省スペース
・NW25接続
見やすいタッチパネルディスプレイ！
972B型：フルレンジ対応 MEMSマイクロピラニ＋コールドカソード
・コールドカソードセンサーを自動的に制御して最適な点火圧力を確保
・ワイドレンジ測定範囲
・省スペース
接続：NW25、ICF70>

東京電子株式会社 ヒット商品！ 短納期！
CC-10：クリスタルゲージ＋コールドカソードゲージ NW25、ICF70接続

MPC 株式会社 ミラプロ タフゲージ ➡ 汚染に強い！
G301CD：ピラニ+BA
CCTG200C：ピラニ+コールドカソード

★ 極高真空計～エクストラクタゲージ

Leybold IM540ユニット
極高真空計測のマストアイテム！
最大5桁の表示＝高精度計測
IEゲージ/2台の接続が可能(別途ピラニやキャパマノを2台併用可能)
IE414：高圧側重視 2×10⁻¹¹ mbar - 1×10⁻² mbar
IE514：低圧側重視 2×10⁻¹² mbar - 1×10⁻⁴ mbar

★ 拡張型真空計

Agilent Technologies XGS600ユニット イオンゲージ計測の定番！
最大12台のセンサーが接続可能（イオンゲージは最大/4台接続可能）
幅広いセンサーラインナップ・各センサー、及び専用カードの購入にて増設が可能

PFEIFFER VACUUM+FAB SOLUTIONS AUTHORIZED RESELLER の新提案!! ポンプ類の運転制御と圧力計測をオールインワンで！
OmniControl®
OmniControl 200, 300, 400
※卓上型
ﾊﾟｯｸﾎﾟﾝﾌﾟ～ﾀｰﾎﾞﾎﾟﾝﾌﾟの連動化
ピラニ、フルレンジゲージ キャパシタンスゲージ、他用途に応じた豊富なセンサー種
大画面タッチパネルで真空システム全体を制御！

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TGkine® SERIES

TGkine®-B

Magnetically Levitated Turbo Molecular Pumps with Integrated Control Unit

1700～4000L/s

- Integrated controller and power supply
- Space saving, energy saving
- Large volume flow rate, high gas throughput
- Various communication options (including EtherCAT)
- In-house magnetic bearing provides stable operation
- Low speed mode

TGkine®-R

Magnetically Levitated Turbo Molecular Pumps

The controller and cables are included.
1700～4000L/s

- Space saving / Energy saving
- High gas throughput
- Various communication options (including EtherCAT)
- In-house magnetic bearing provides stable operation
- Low speed mode
- Pump body memory to store the hours and other operational data

TG-MR SERIES

Radiation-hardened Type Maglev Turbo Molecular Pumps

Developed for operation under a high radiation environment.
High tolerance against radiation.

TG-MS / TG-FS SERIES

Magnetically Shielded Type Turbo Molecular Pumps

- Can operate in a magnetic field without too muchbraking effect or heating the rotor.
- Applicable to all the Osaka Vacuum TMP
- Suitable for an accelerator.

TG-MM SERIES

Low helium permeation type Maglev Turbo Molecular Pumps

- No polymer on sealing (all metal gaskets, glass hermetic connector)
- For applications that require low Helium permeation
- Tolerant to radiation (up to around 1 MGy)

ST SERIES

Turbo Molecular Pumping System

- Simple operation enables evacuation to a high vacuum.
- Easy-to-use touch panel interface.
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- Resistant to external disturbances; can be moved during pump operation.
- Optional equipment can be installed as needed.
- Proven use in the medical accelerator systems.

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【Official website】
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Osaka Vacuum U.S.A., Inc.	48000 Fremont Blvd., Fremont, CA 94538, U.S.A. TEL: 1-510-770-0100 FAX: 1-510-770-0104
Shanghai Osaka Vacuum, Ltd.	No.1510, Chuanqiao Rd., Pudong, Shanghai 201206, P.R. China TEL: 86-21-5031-1522 FAX: 86-21-5031-1523

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1300MHz 7kW CW All Solid-State RF Amplifier

Model : CA1300BW1-6068R-SL

SPECIFICATIONS @＋25℃

Frequency Range	: 1300MHz±0.5MHz (Standard Freq.)
Small Signal Gain	: ＋60.0dB (min.)
Output Power (CW)	: 7kW (min.) @1dB Comp.
Amplitude Flatness	: 5% (max.) @1300MHz±100kHz
Phase Linearity	: 5deg (max.) @1300MHz±100kHz
Delay	: 300ns (max.)
Phase Variation	: 10deg (max.) @Po=1kW～7kW
Efficiency	: 40% (min.) @Po=7kW
AC to RF Efficiency	
・Optimum Efficiency Performance	＞42.1% at Vdd ＋42VDC Control
・Optimum P@-1dB Performance	＞41.2% at Vdd ＋45VDC Control
Impedance	: 50Ω
AC Supply Input	: AC480V±5%／3φ, 60Hz AC120V±5%／1φ, 60Hz
Consumption Power	: 17.5kVA(max.)
Connectors	: RF - IN N - FEMALE RF - OUT WR650
Size	: (W)762mm×(D)1270mm×(H)1688.5mm (Excluding Projection)
Weight	: 793kg (max.)
Cooling	: Forced Air Cooling and Water Cooling
Protection Circuits	: Over Temperature Protection
(All not listed)	Power Supply Voltage Protection Output Over Power Protection
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Nodica Group

Scandinova Systems established the group's parent company, the "Nodica Group", at the end of 2024 together with three global industry-leading companies in their common fields (Scanditronix(Sweden), Microwave Amp(UK) and IECO(Finland)).
Scandinova will combine and develop the know-how it has cultivated over more than 25 years with the new technologies of these three companies to deliver the world's best products and high quality services in the fields of medicine, science and technology, and consumer products.

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Our Services

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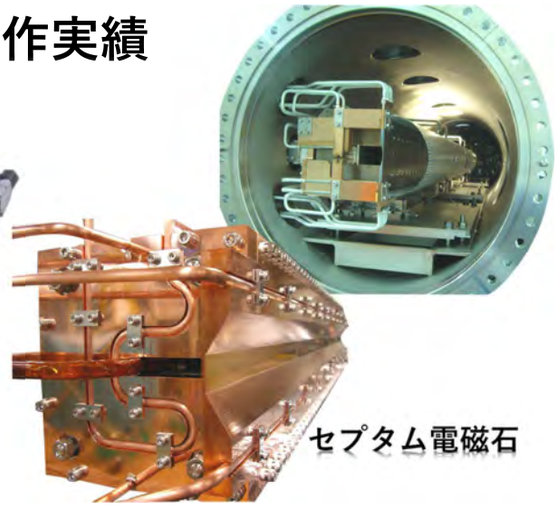
モニター



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- Particle size classification:0.25～3.6μm/7class
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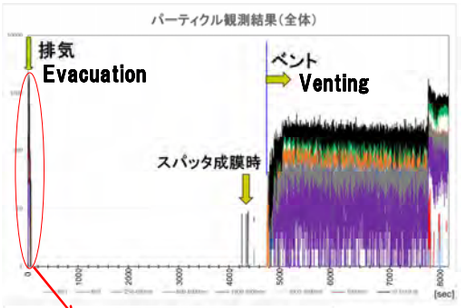
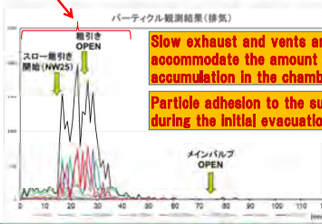
Slow pumping &
Slow bent system

Wexx Co.,Ltd.

真空中パーティクルモニタ
Vacuum Particle Sensor(in situ)

Batch-type sputtering equipment
Particles during evacuation/venting





Slow exhaust and vents are required to accommodate the amount of particle accumulation in the chamber.

Particle adhesion to the substrate is determined during the initial evacuation stage.

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Wi-Fi Information

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